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Furutani

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(45) **Date of Patent: Sep. 13, 2016**

(54) **OPTICAL CONDENSER, ROTATIONAL AXIS SETTING METHOD THEREFOR, AND HEAT COLLECTION APPARATUS AND SOLAR POWER GENERATION APPARATUS EQUIPPED WITH OPTICAL CONDENSER**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 202 days.

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Feb. 29, 2012 (JP) 2012-043863

(51) **Int. Cl.**
F03G 7/00 (2006.01)
F03G 6/06 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC .. ***F03G 6/06*** (2013.01); ***F24J 2/07*** (2013.01); ***F24J 2/1047*** (2013.01); ***F24J 2/16*** (2013.01);
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CPC F03G 2006/062; F03G 6/06; F24J 2/07; F24J 2/1047; F24J 2/16; G02B 7/1827; G02B 7/183; Y02E 10/41; Y02E 10/46
USPC 126/572, 600
See application file for complete search history.

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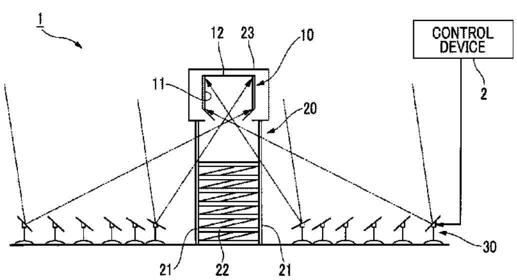
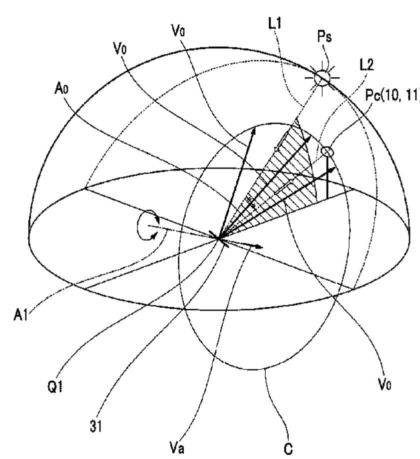
Primary Examiner — Jesse Bogue
(74) *Attorney, Agent, or Firm* — Westerman, Hattori, Daniels & Adrian, LLP

(57) **ABSTRACT**

Optical axis vectors indicating a direction of an optical axis of a mirror structure that directs the light from the sun at a plurality of times on a predetermined day to a condensed position are obtained for each of the plurality of times. Next, a cone having generatrices along which direction segments of the optical axis vectors for each of the plurality of times extend is determined, and a cone central axis vector indicating a direction of a central axis of the cone is obtained. A first rotational axis of an optical condenser is set to be parallel to the cone central axis vector.

17 Claims, 26 Drawing Sheets





(51) **Int. Cl.**

F24J 2/07	(2006.01)
F24J 2/10	(2006.01)
F24J 2/16	(2006.01)
G02B 7/182	(2006.01)
G02B 7/183	(2006.01)

(52) **U.S. Cl.**

CPC ***G02B 7/183*** (2013.01); ***G02B 7/1827*** (2013.01); *F03G 2006/062* (2013.01); *Y02E 10/41* (2013.01); *Y02E 10/46* (2013.01)

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FIG. 1

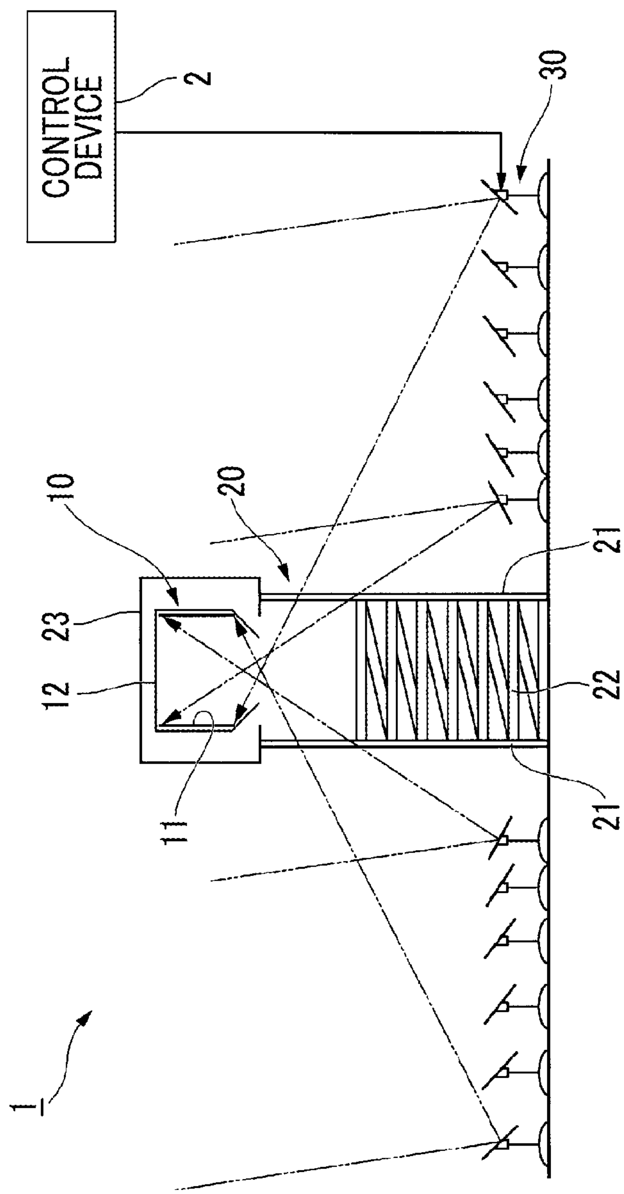


FIG. 2

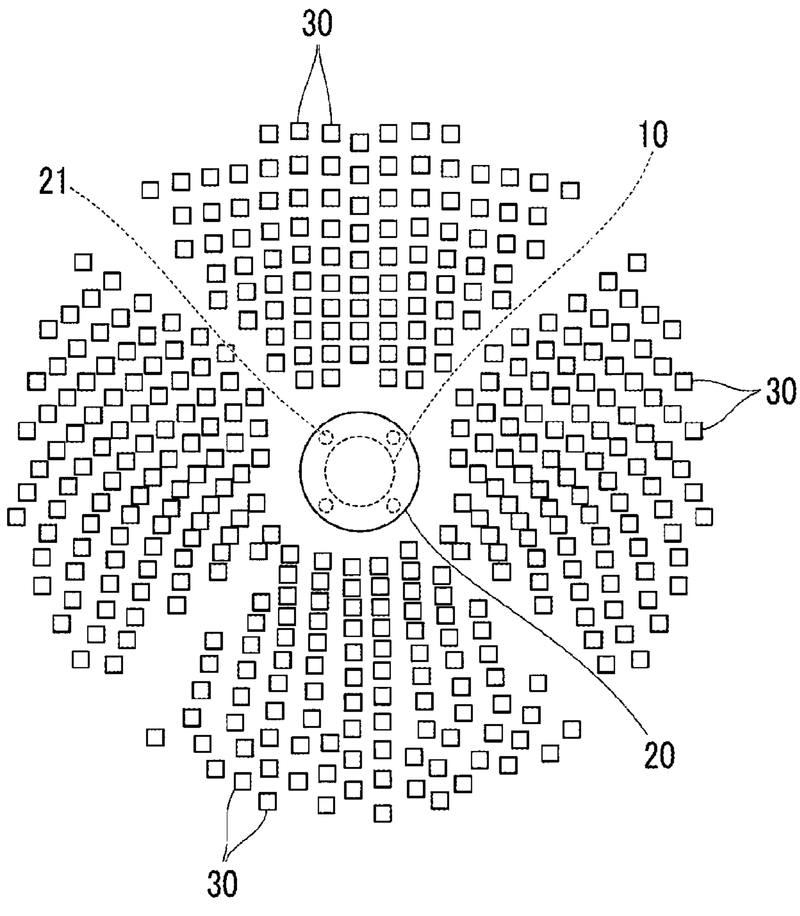
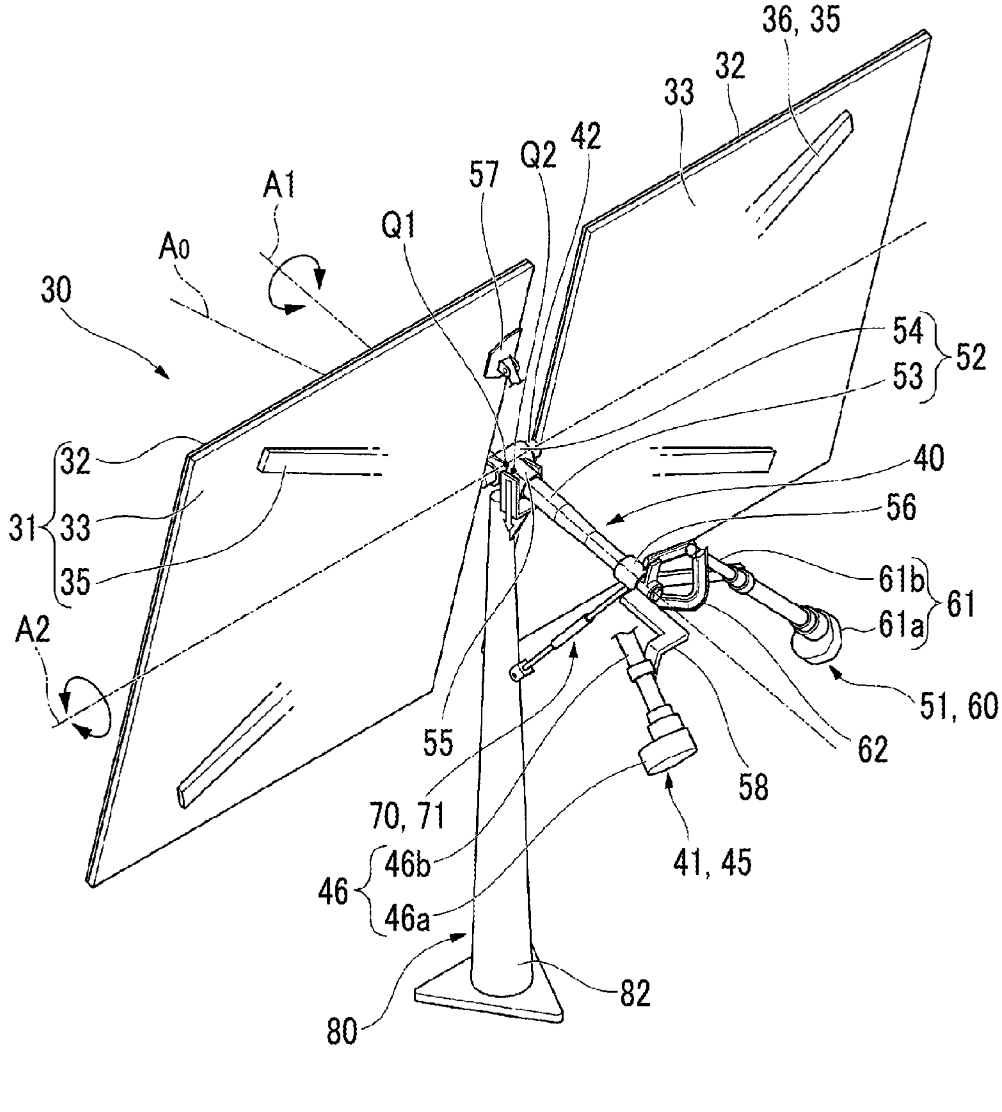


FIG. 3


36, 35
32
33
42
Q2
57
A1
Q1
A0
30
54
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40
32
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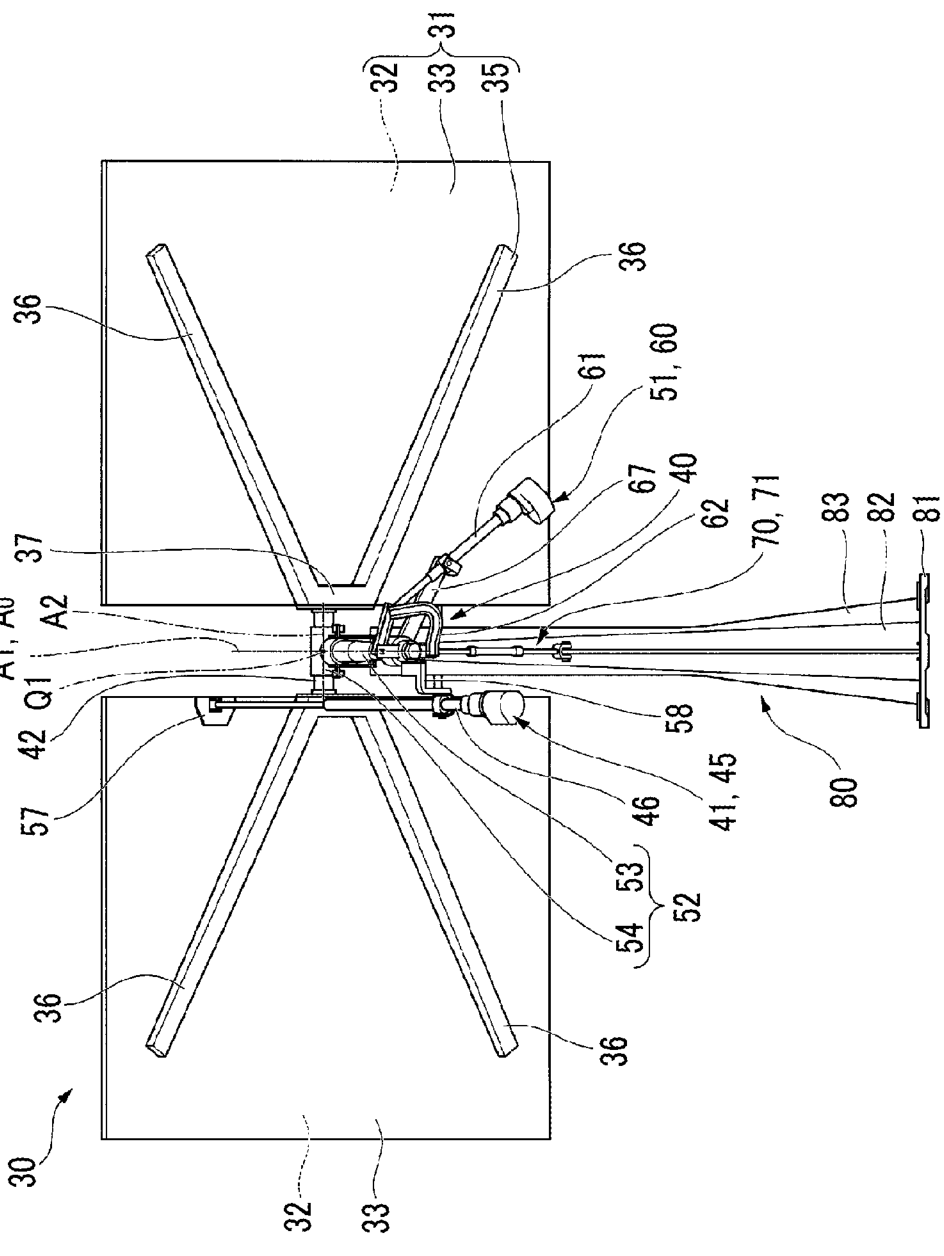
33
35
56
61b
61
61a
A2
51, 60
55
62
58
70, 71
41, 45
46
46b
46a
82
80

FIG. 4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51, 60
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70, 71
83
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81
A1, A0
A2
Q1
42
57
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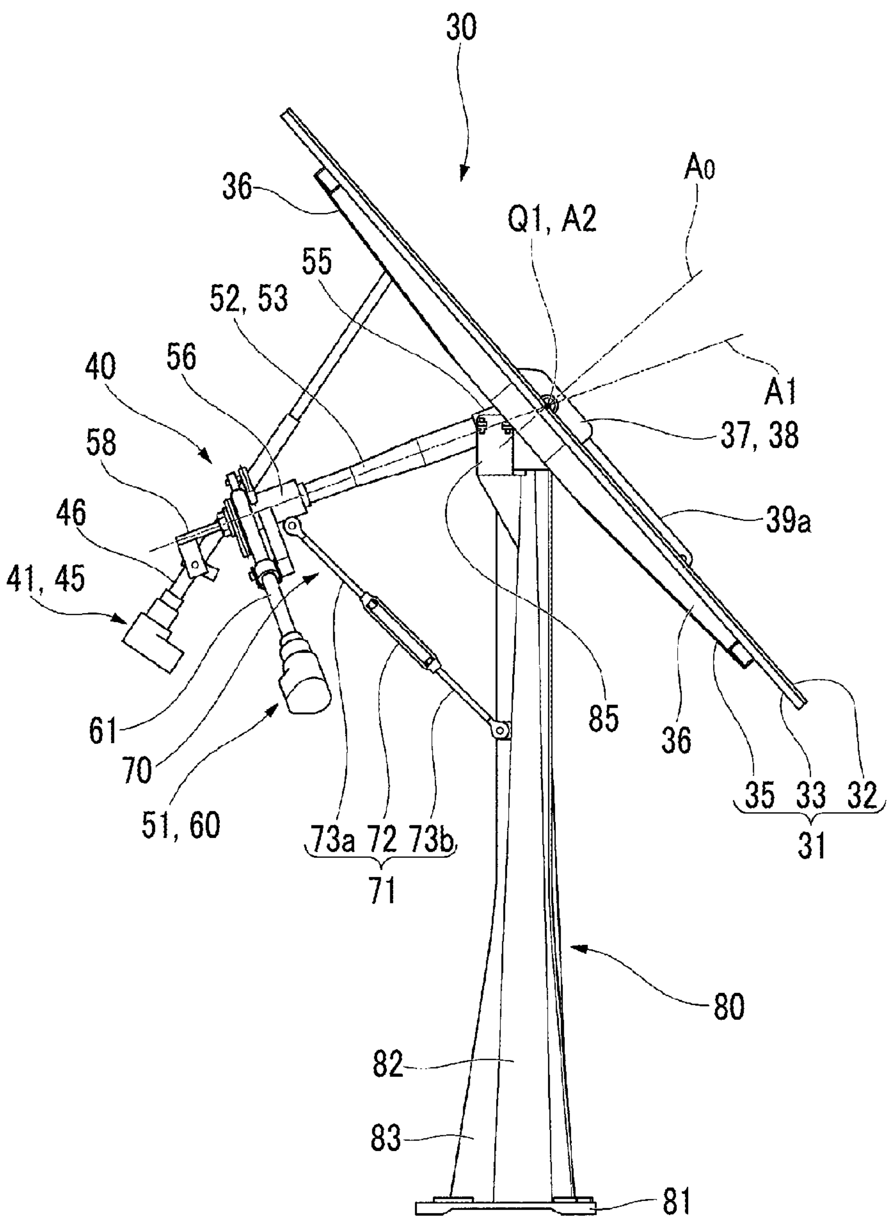
41, 45
80
53
54
52
30

FIG. 5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36
Q1, A2
A0
55
52, 53
A1
40
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37, 38
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39a
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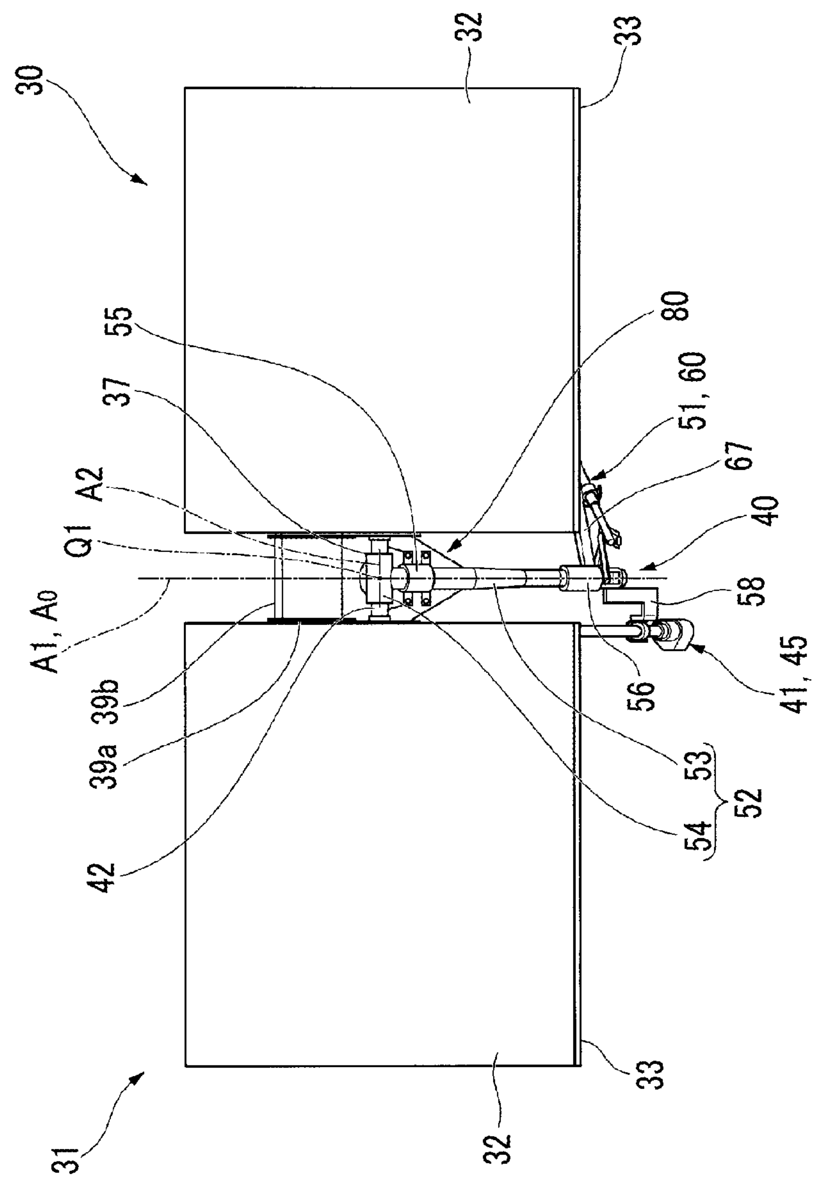
70
51, 60
73a 72 73b
71
35 33 32
31
80
82
83
81

FIG. 6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32
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55
80
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51, 60
67
A2
Q1
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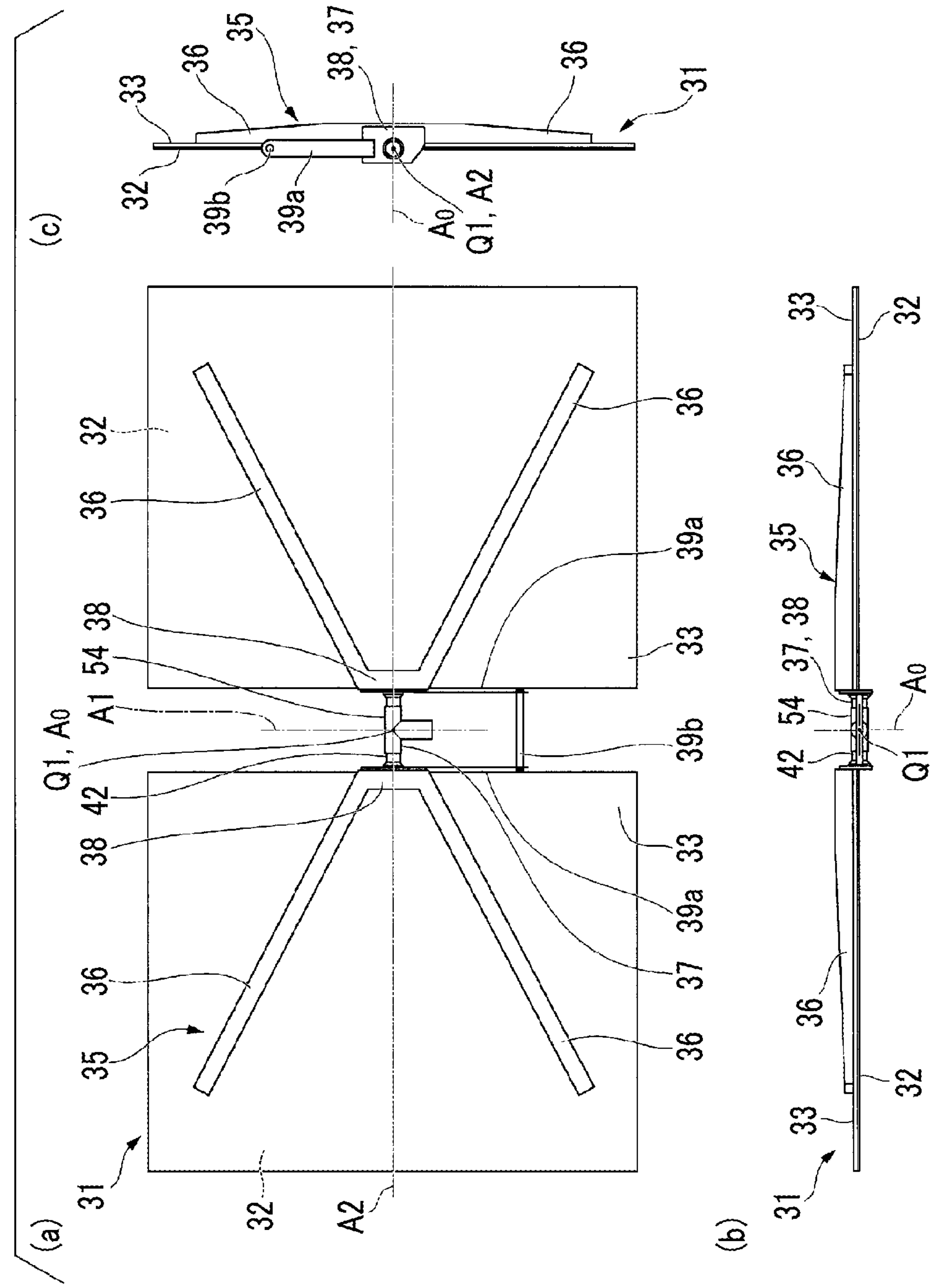
A1, A0
39b
39a
56
41, 45
53
52
54
42
31
32
33

FIG. 7


(a)
(b)
(c)
31
32
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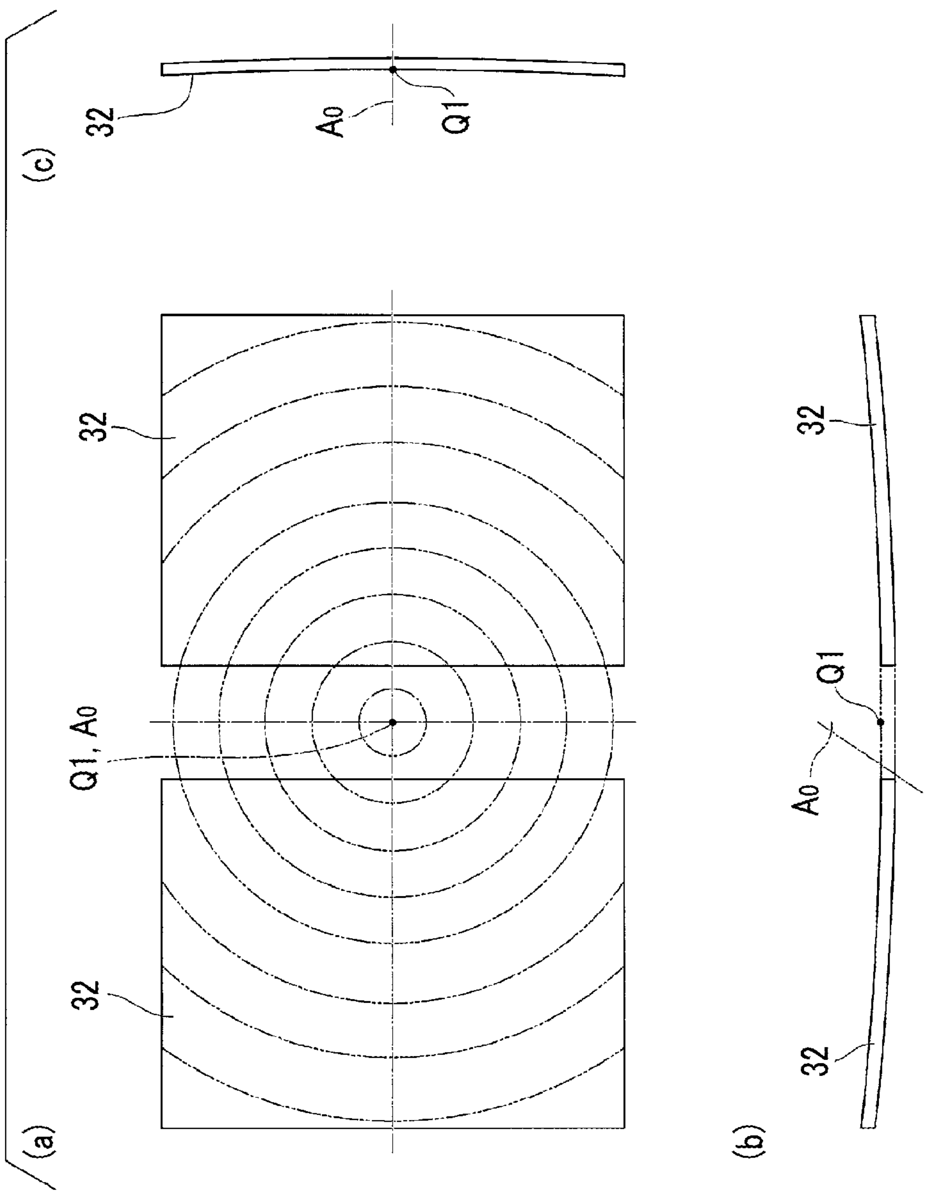
38, 37
37, 38
39a
39b
42
54
A1
A2
Q1, A0
Q1, A2
A0
Q1

FIG. 8



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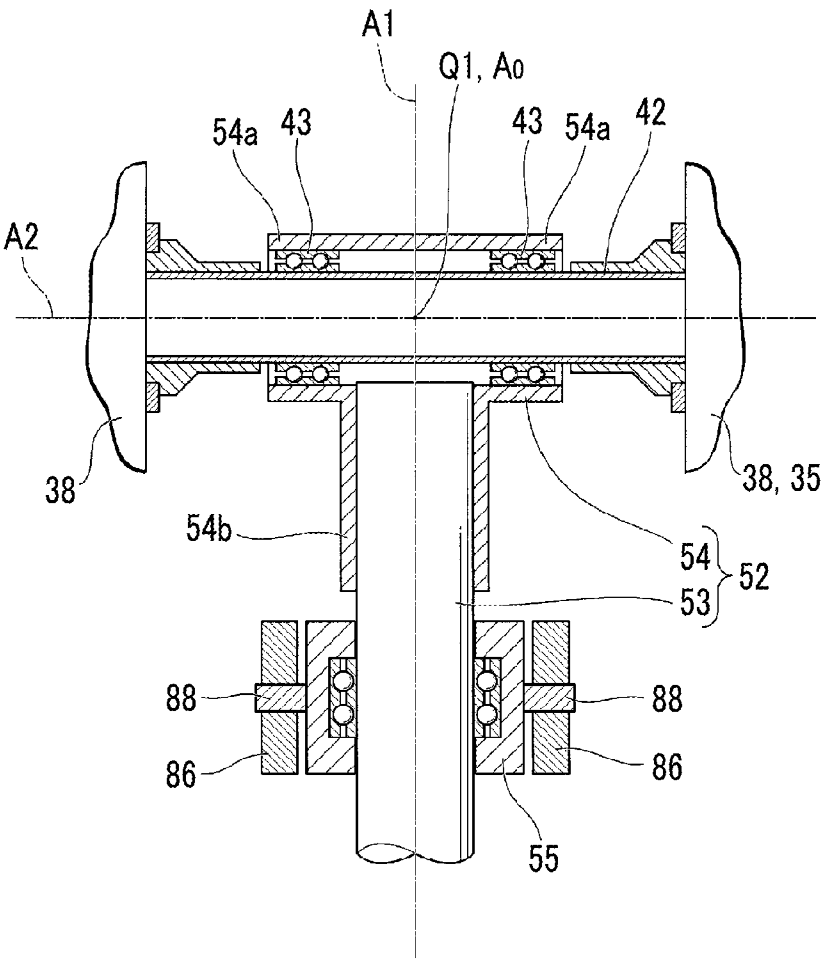


FIG. 10

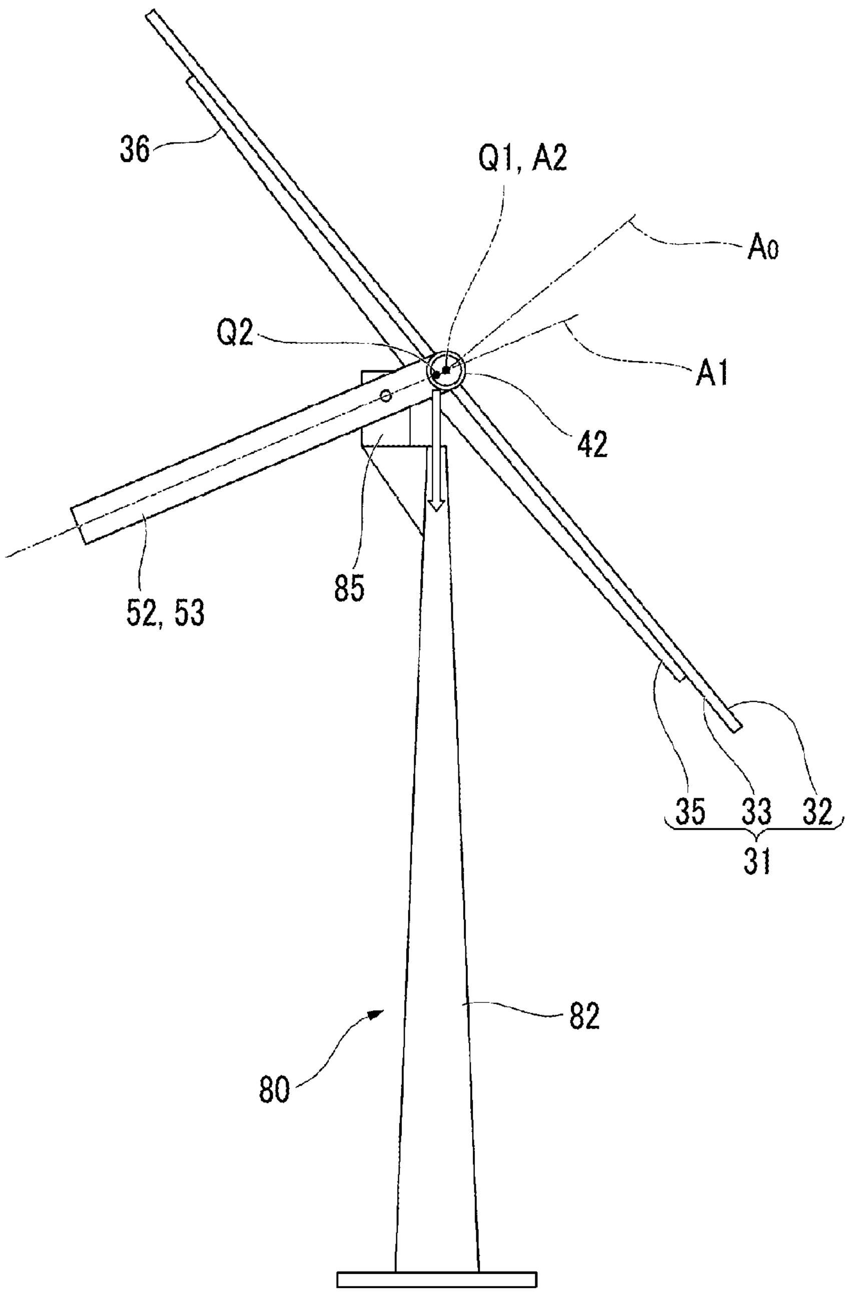


FIG. 11

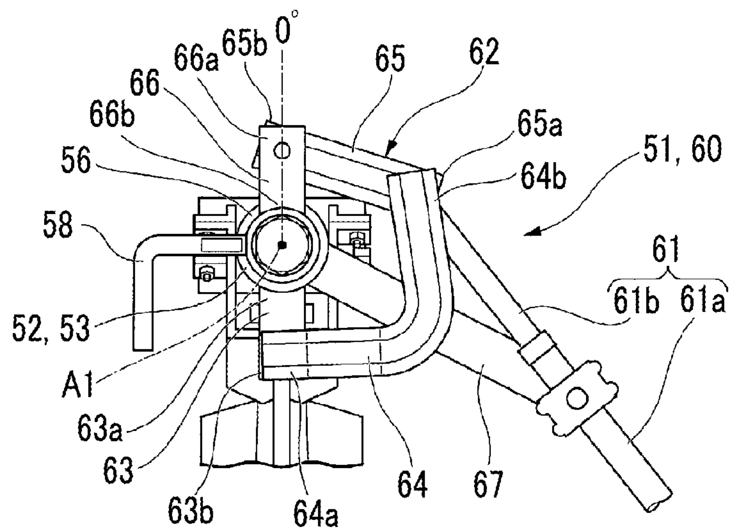

0°
65b
66a
66
66b
56
58
52, 53
A1
63a
63
63b
64a
64
67
65
62
65a
64b
51, 60
61
61b
61a

FIG. 12

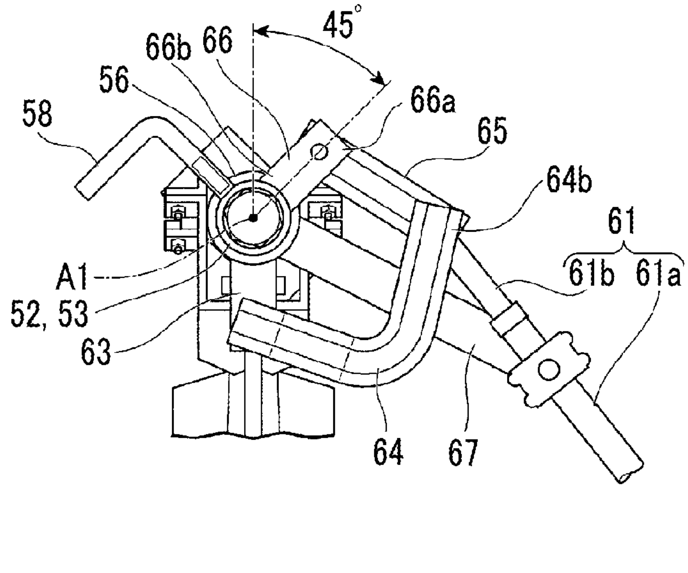

45°
66b
66
56
58
66a
65
64b
61
61b
61a
A1
52, 53
63
64
67

FIG. 13

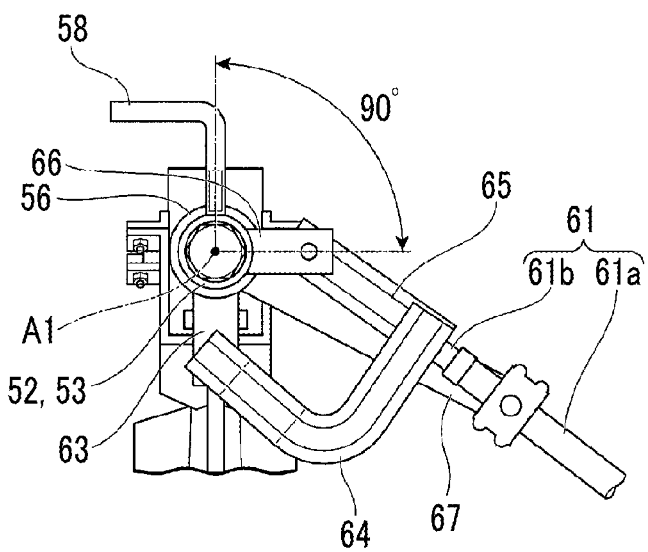


FIG. 14

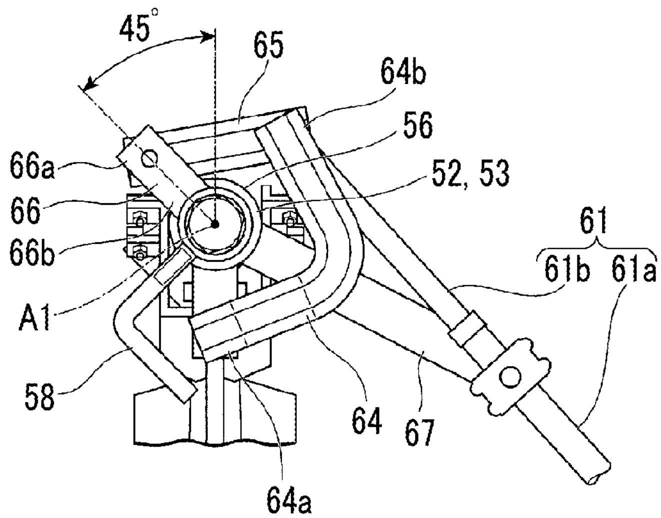

45°
65
64b
56
66a
52, 53
66
61
66b
61b 61a
A1
58
64
67
64a

FIG. 15

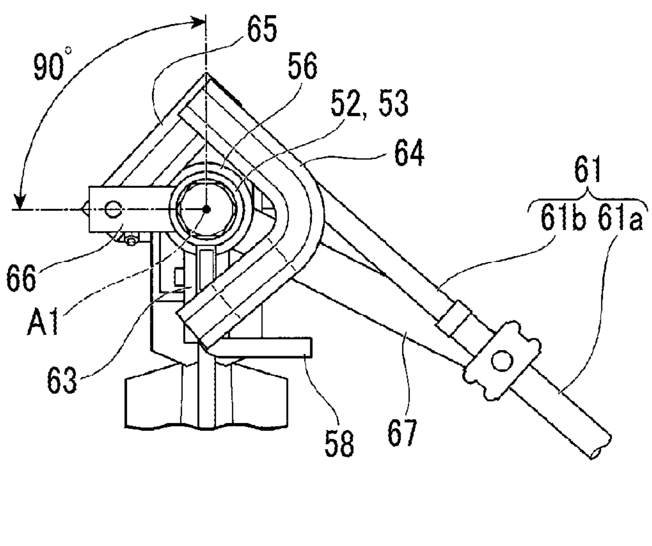

65
90°
56
52, 53
64
61
61b 61a
66
A1
63
58
67

FIG. 16

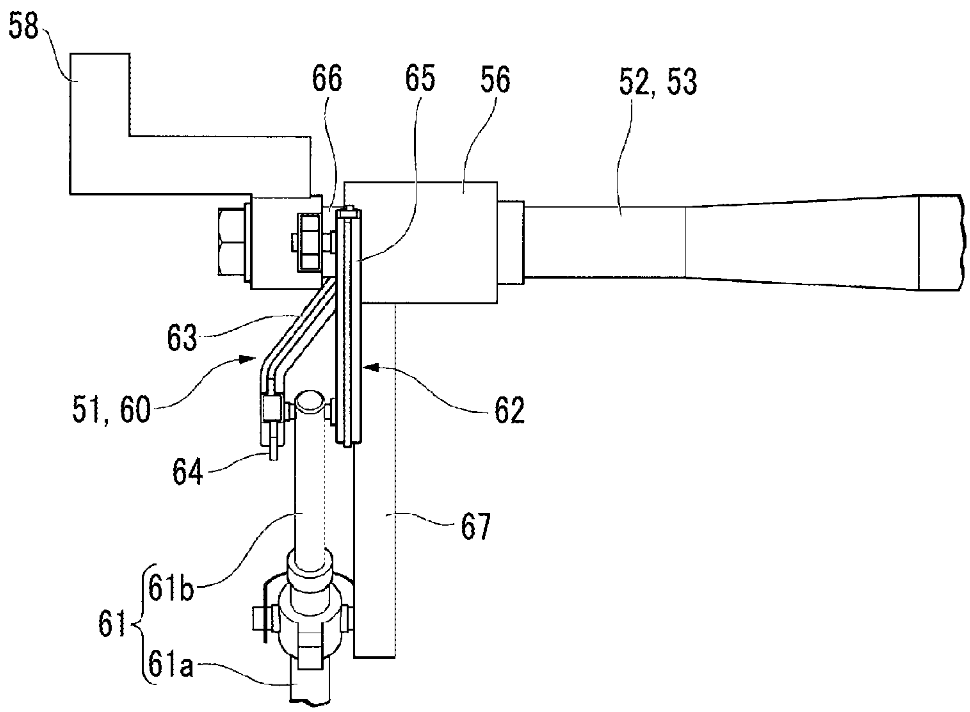


FIG. 17

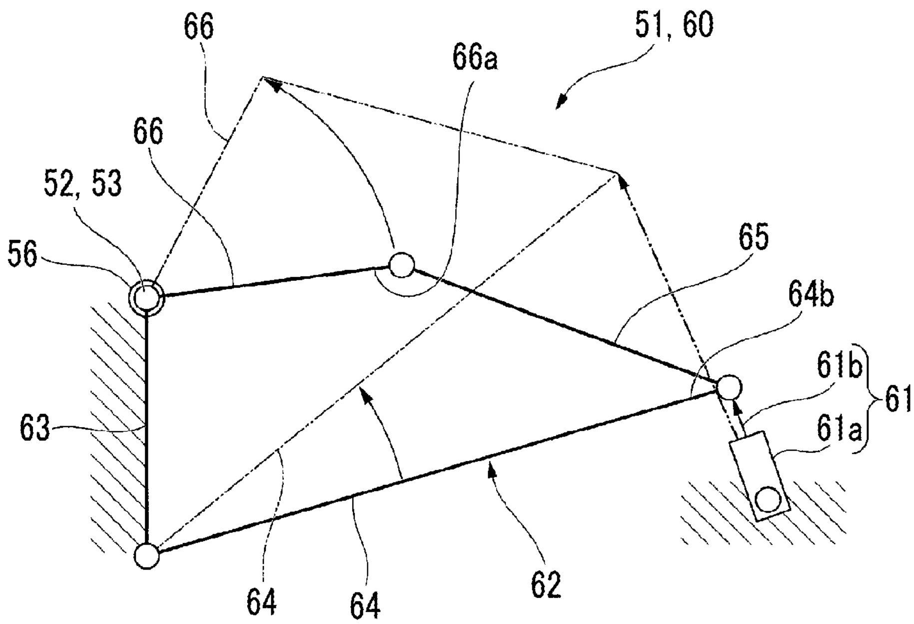


FIG. 18

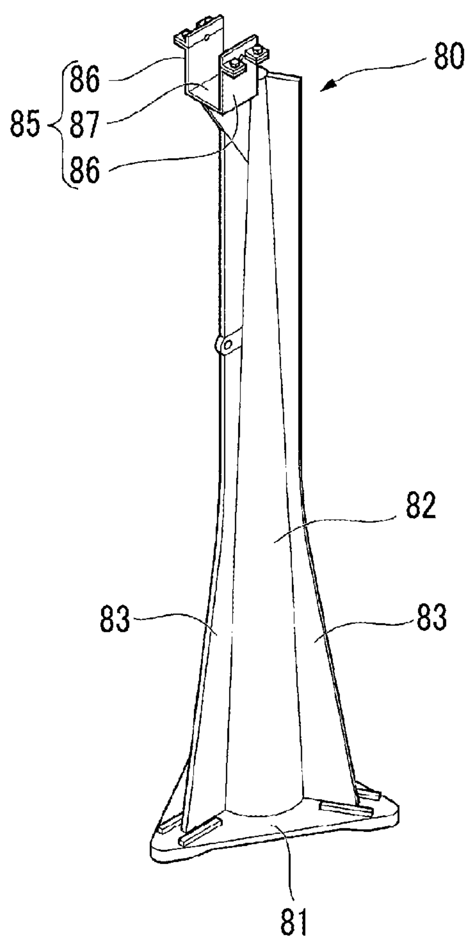


FIG. 19

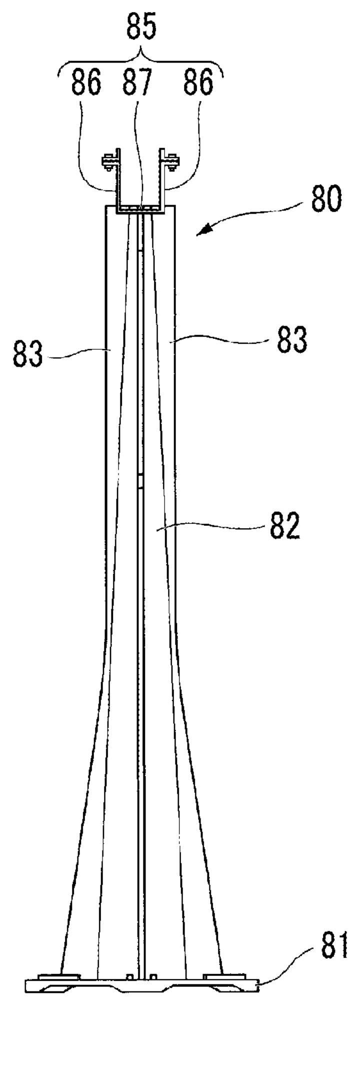


FIG. 20

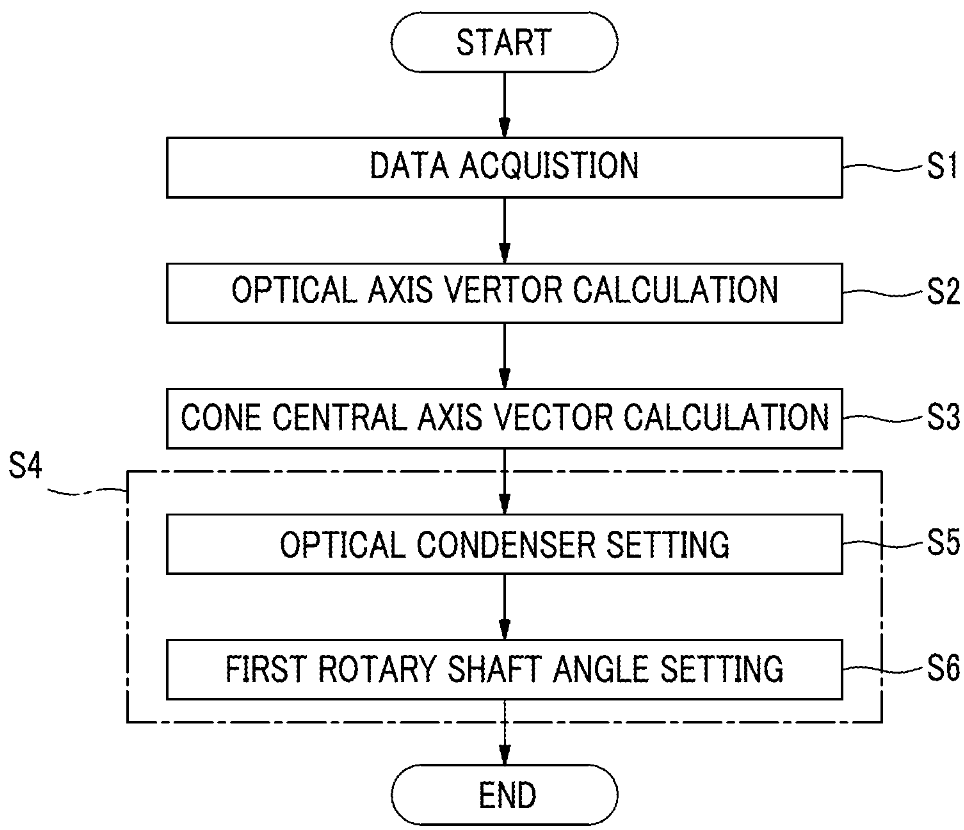

START
DATA ACQUISTION
S1
OPTICAL AXIS VERTOR CALCULATION
S2
CONE CENTRAL AXIS VECTOR CALCULATION
S3
S4
OPTICAL CONDENSER SETTING
S5
FIRST ROTARY SHAFT ANGLE SETTING
S6
END

FIG. 21

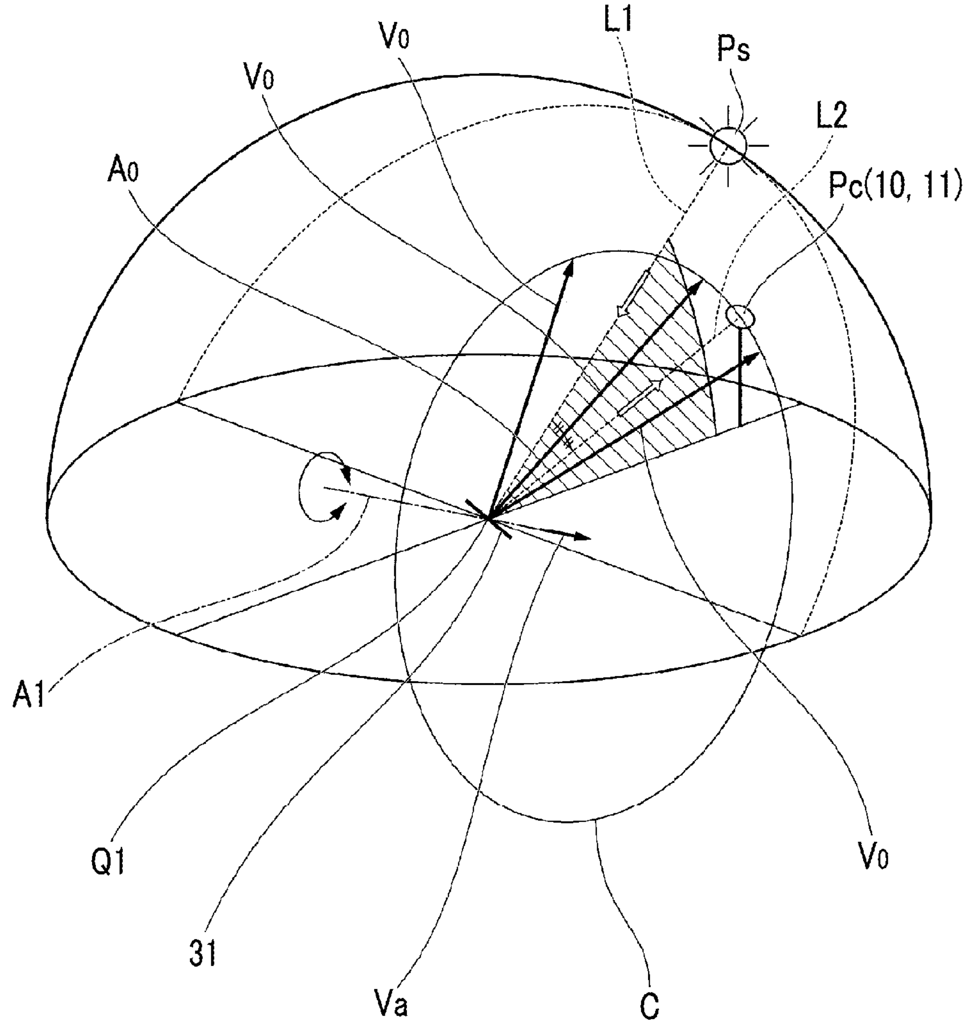


FIG. 22

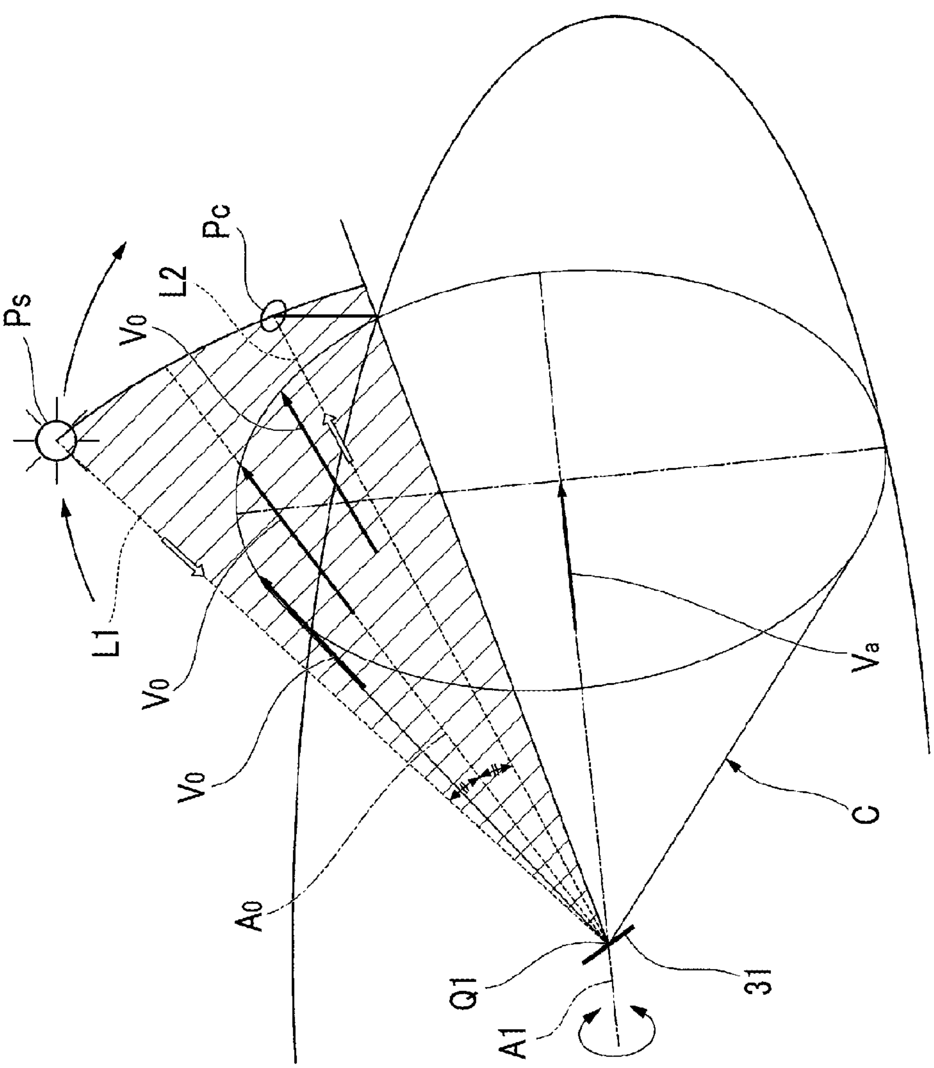


FIG. 23

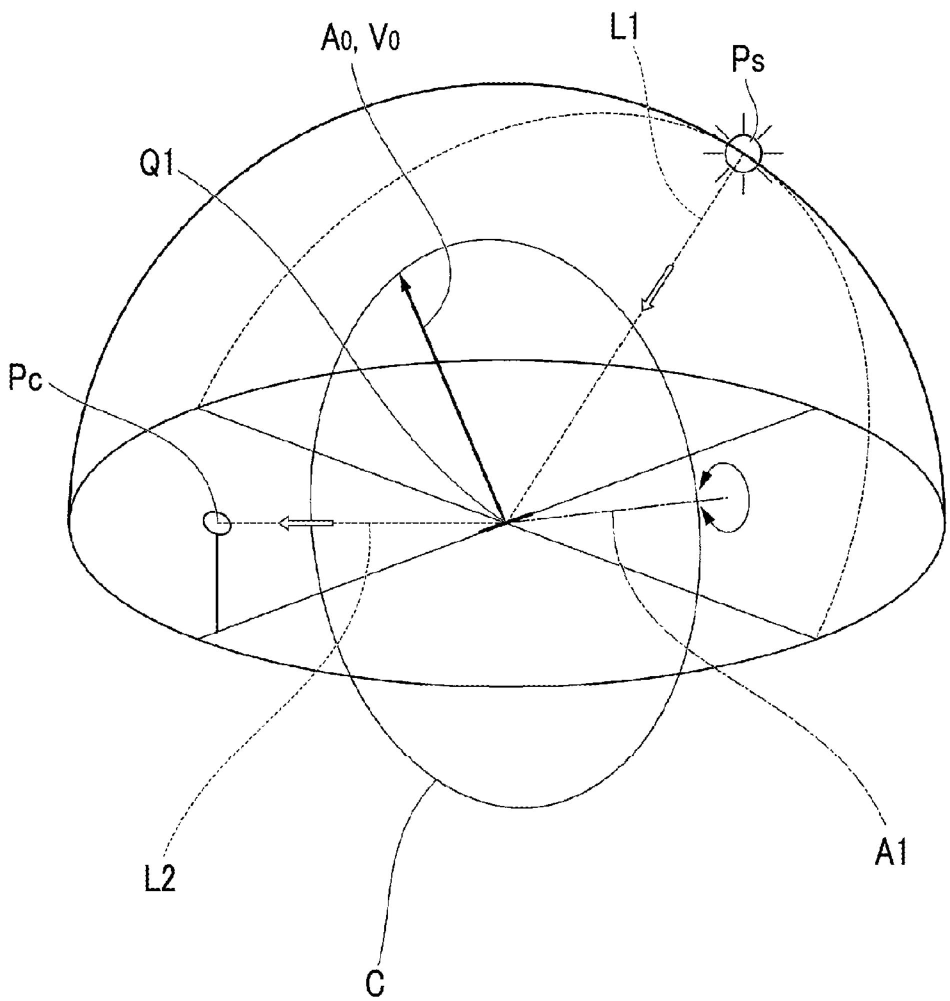


FIG. 24

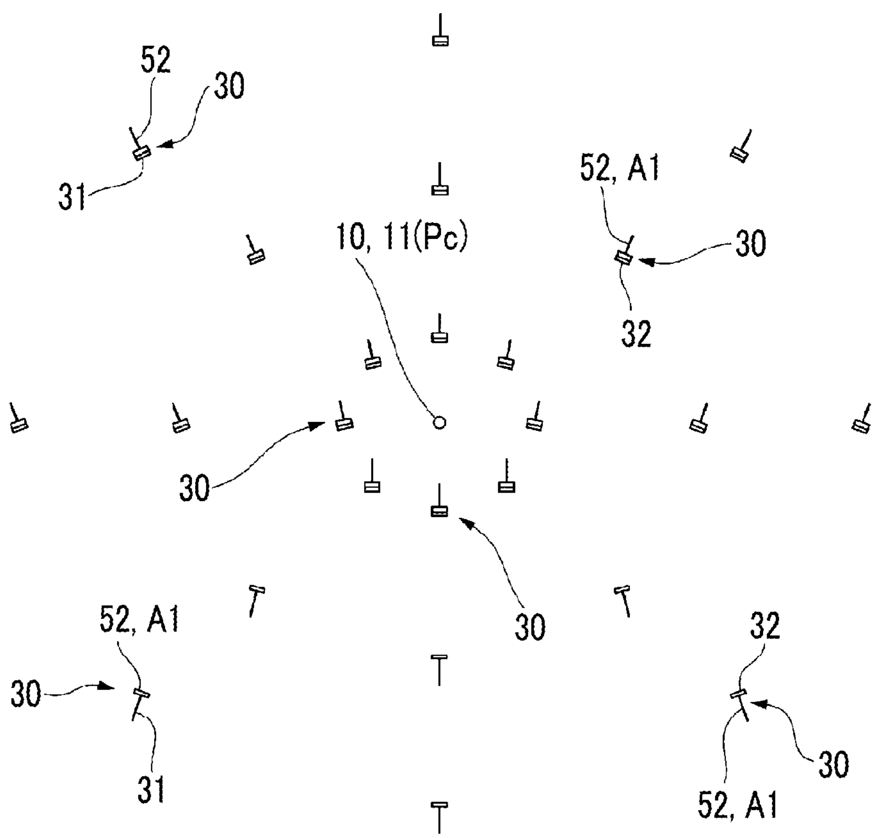


FIG. 25A

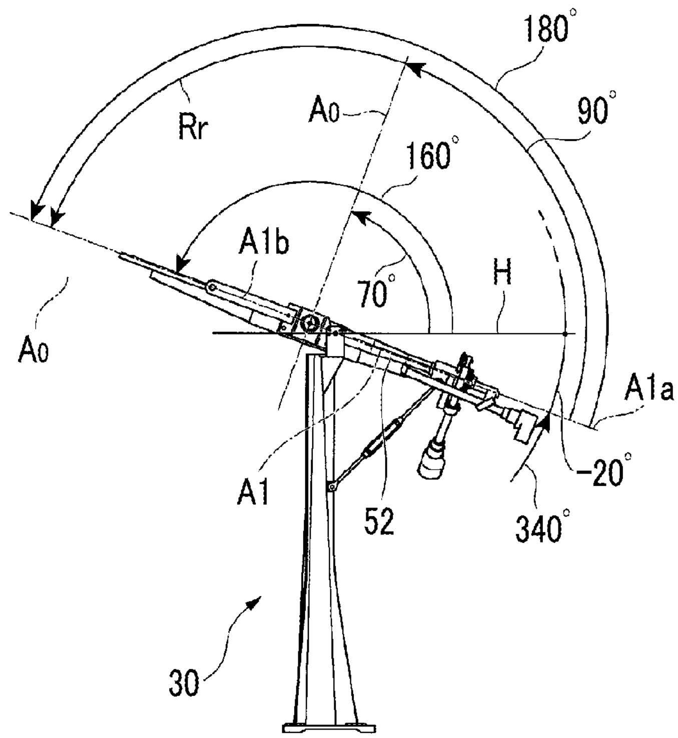


FIG. 25B

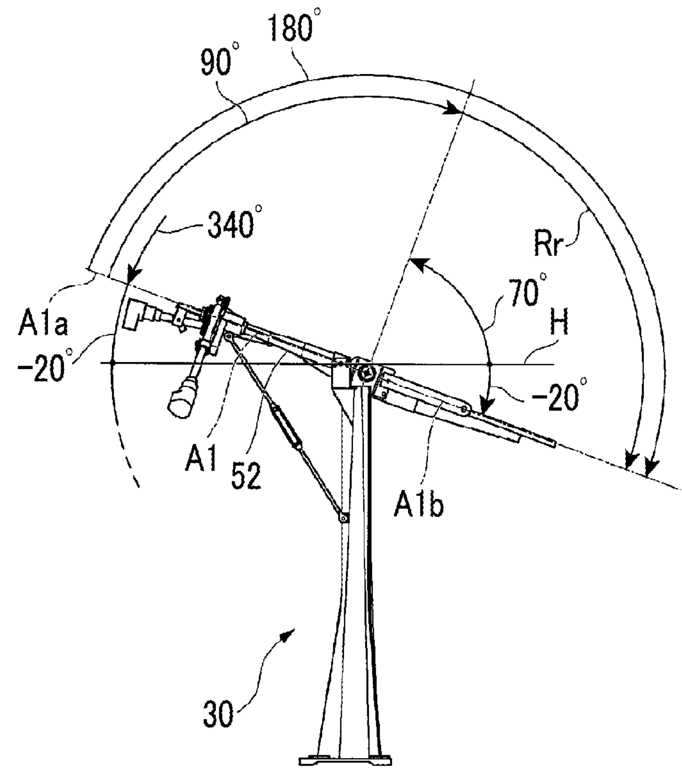


FIG. 26

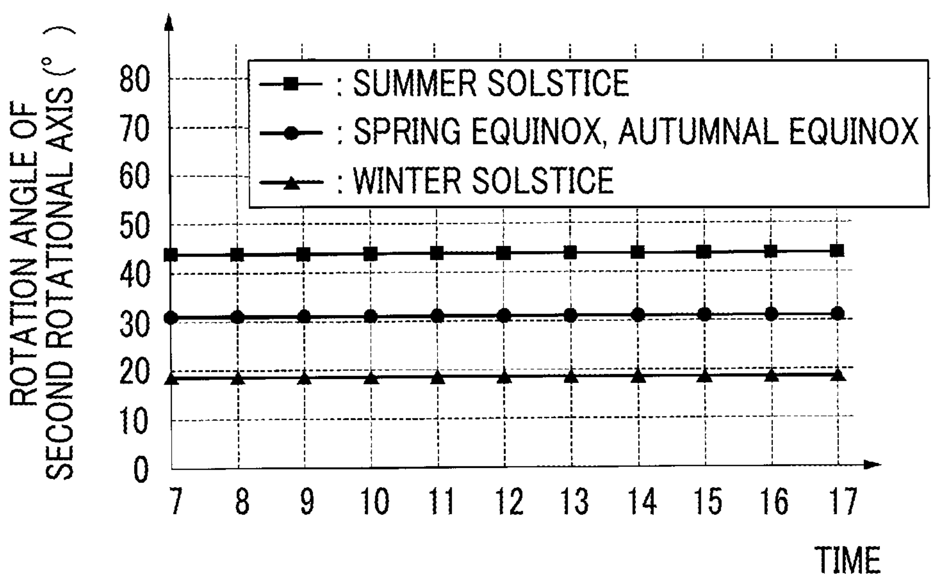
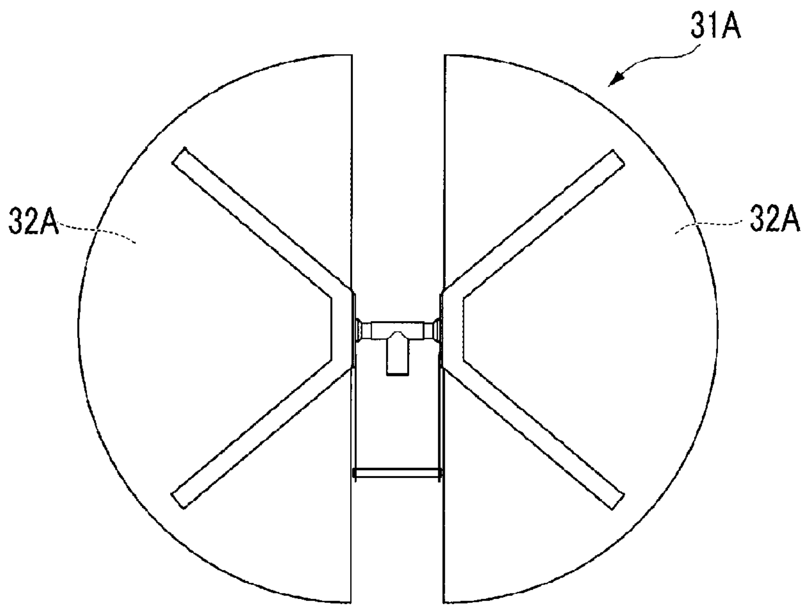

ROTATION ANGLE OF SECOND ROTATIONAL AXIS (°)
80
70
60
50
40
30
20
10
0
7
8
9
10
11
12
13
14
15
16
17
TIME
: SUMMER SOLSTICE
: SPRING EQUINOX, AUTUMNAL EQUINOX
: WINTER SOLSTICE

FIG. 27



OPTICAL CONDENSER, ROTATIONAL AXIS SETTING METHOD THEREFOR, AND HEAT COLLECTION APPARATUS AND SOLAR POWER GENERATION APPARATUS EQUIPPED WITH OPTICAL CONDENSER

TECHNICAL FIELD

The present invention relates to an optical condenser that reflects sunlight with a mirror to condense the sunlight onto a predetermined condensed position, a rotational axis setting method therefor, and a heat collection apparatus and a solar power generation apparatus equipped with the optical condenser.

Priority is claimed on Japanese Patent Application No. 2012-043863, filed Feb. 29, 2012, the content of which is incorporated herein by reference.

BACKGROUND ART

In recent years, apparatuses using heat energy obtained by condensing sunlight onto a predetermined position as environment-friendly clean energy have been briskly developed.

As an optical condenser that condenses sunlight onto a predetermined position, for example, there is an apparatus described in the following PTL 1. This optical condenser includes a mirror and a driving device that turns the mirror around two rotational axes having mutually different orientations. In this optical condenser, one rotational axis of the two rotational axes is set to be parallel to the earth's axis. That is, in this optical condenser, an equatorial telescope type is adopted as the driving device.

CITATION LIST

Patent Literature

[PTL 1] Japanese Unexamined Patent Application Publication No. 55-96910

SUMMARY OF INVENTION

Technical Problem

In the optical condenser described in the above PTL 1, when the sun is simply tracked, the mirror may be turned around the rotational axis parallel to the earth's axis. However, practically, it is necessary to direct the light from the sun making the diurnal motion to a fixed condensed position. Therefore, in order to respond to the diurnal motion of the sun, it is necessary to turn the mirror around the rotational axis parallel to the earth's axis and also turn the mirror around the remaining rotational axis.

That is, in the optical condenser described in the above PTL 1, it is necessary to turn the mirror around the two rotational axes in order to respond to the diurnal motion of the sun. Therefore, there is a problem that not only does a control system of the driving device become complicated but also the energy consumption for driving the mirror is large.

Thus, an object of the invention is to provide an optical condenser, a rotational axis setting method therefor, and a heat collection apparatus and a solar power generation apparatus equipped with the optical condenser in which a control system of a driving device can be simplified and the energy consumption of the driving device can be suppressed.

Solution to Problem

An optical condenser related to the invention for solving the above problems is an optical condenser that includes a mirror structure having one or more mirrors and reflects sunlight with the mirrors of the mirror structure to condense the sunlight onto a predetermined condensed position. The optical condenser includes a first driving part that turns the mirrors with a first rotational axis as a center, and a second driving part that turns the mirrors with a second rotational axis perpendicular to the first rotational axis as a center. The first rotational axis is set to be parallel to a central axis of a cone drawn by a track of an optical axis of the mirror structure that directs the light from the sun making a diurnal motion to the condensed position.

The direction of the optical axis of the mirror structure that directs the light from the sun at a certain time to the fixed condensed position is a direction in which an angle formed between an imaginary line connecting the sun and the principal point (a point passing through the optical axis among points on the reflecting surfaces of the mirrors or extending surfaces of the reflecting surfaces) of the mirror structure and an imaginary line connecting the principal point of the mirror structure and the condensed position is bisected. The track of the optical axis accompanying the diurnal motion of the sun draws a side peripheral surface of a certain cone. For this reason, if the first rotational axis is set to be parallel to the central axis of the cone and if the mirror structure is first turned with the second rotational axis as a center so that the sunlight reflected by the mirror structure is radiated to the condensed position, the light of the sun making the diurnal motion can be radiated to the fixed condensed position, basically and simply by turning the mirror structure with the first rotational axis as a center from then.

Hence, in the optical condenser, a control system of the driving device can be simplified, and the energy consumption of the driving device can be suppressed.

Here, in the optical condenser, reflecting surfaces of the one or more mirrors of the mirror structure may form one symmetrical plane of revolution, and a symmetrical axis of revolution of the symmetrical plane of revolution may constitute the optical axis of the mirror structure.

Additionally, the optical condenser may further include an elevation angle changing part that changes an angle of the first rotational axis with respect to a horizontal surface.

In a heat collection apparatus, a plurality of the optical condensers are often provided. In this case, relative positions with respect to condensed positions vary for each of the optical condensers, and it is necessary to change the angle of the first rotational axis with respect to the horizontal surface. Since the optical condenser has the elevation angle changing part, when a plurality of the optical condensers are provided, the angle of the first rotary shaft with respect to the horizontal surface can be changed for each of the optical condensers.

Additionally, in the optical condenser having the elevation angle changing part, an angle range of the mirrors that are turned with the second rotational axis as a center in the second driving part may be within a predetermined angle range on the basis of the first rotational axis, and the elevation angle changing part may change the angle of the first rotational axis with respect to the horizontal surface between a downward state where one side of the first rotational axis is made equal to or lower than the other side on the basis of the second rotational axis and an upward state where the one side is made higher than the other side.

In the optical condenser, even if the angle range of the mirrors that are turned with the second rotational axis as a center is a limited range, an angle range to be used can be included within the angle range of the mirrors that are turned with the second rotational axis as a center.

A heat collection apparatus related to the invention for solving the above problems includes the optical condenser; and a heat receiver that heats a medium by sunlight condensed by the optical condenser.

A solar power generation apparatus related to the invention for solving the above problems includes the optical condenser; a heat receiver that heats a medium from sunlight condensed by the optical condenser; a turbine that is driven by the medium heated by the heat receiver; and a generator that generates electricity through the driving of the turbine.

A rotational axis setting method related to the invention for solving the above problems is a rotational axis setting method in an optical condenser including a mirror structure having one or more mirrors and a driving device that turns the mirror structure around a rotational axis to direct sunlight reflected by the mirrors of the mirror structure to a predetermined condensed position. The rotational axis setting method includes a data acquisition step of acquiring global position data of the mirror structure, global position data of the condensed position, and solar position data based on the position of the mirror structure for each of a plurality of times on a predetermined day in one year; an optical axis vector calculating step of obtaining optical axis vectors indicating a direction of an optical axis of the mirror structure that directs the light from the sun at the plurality of times on the predetermined day to the condensed position for each of the plurality of times; a cone central axis vector calculating step of determining a cone having generatrices along which direction segments of the optical axis vectors for each of the plurality of times extend, and obtaining a cone central axis vector indicating a direction of a central axis of the cone; and a rotational axis setting step of setting the rotational axis to be parallel to the cone central axis vector.

In the setting method, similar to the above optical condenser, if the sunlight reflected by the mirror structure is first made to be radiated to the condensed position, the light of the sun making the diurnal motion can be radiated to the fixed condensed position, basically and simply by turning the mirror structure with one rotational axis as a center from then. Hence, if the rotational axis is set by the setting method, the control of the driving device can be simplified, and the energy consumption of the driving device can be suppressed.

Here, in the rotational axis setting method, the driving device may include a first driving part that turns the mirrors with a first rotational axis as the rotational axis as a center, and a second driving part that turns the mirrors with a second rotational axis perpendicular to the first rotational axis as a center. The setting method may further include a step of changing a turning angle of the mirrors centered on the second rotational axis so as to correspond to a change in an elevation angle of the sun accompanying a diurnal change.

In the setting method, it is possible to respond to a change in the elevation angle of the sun accompanying a seasonal change.

Additionally, in the rotational axis setting method, the rotational axis setting step may include an optical condenser installation step of installing the optical condenser so that the mirror structure is located at a position indicated by the position data of the mirror structure acquired in the data acquisition step and the orientation of the first rotational axis becomes the orientation indicated by the cone central axis vector; and a first rotary shaft angle setting step of setting the first rotational axis so that the angle of the first rotational axis with respect to the horizontal surface becomes the angle of the cone central axis vector with respect to the horizontal surface.

In this case, an angle range of the mirrors that are turned with the second rotational axis as a center in the second driving part may be within a predetermined angle range on the basis of the first rotational axis. In the first rotary shaft angle setting step, the first rotational axis may be set in a state where the predetermined angle range based on the first rotational axis is able to include a predetermined angle range where the mirrors are turned with the second rotational axis as a center, out of a downward state where the angle of one side of the first rotational axis with respect to the horizontal surface on the basis of the second rotational axis becomes the angle of the cone central axis vector with respect to the horizontal surface and the one side of the first rotational axis is made equal to or lower than the other side, and an upward state where the angle of the other side of the first rotational axis with respect to the horizontal surface becomes the angle of the cone central axis vector with respect to the horizontal surface and the one side of the first rotational axis is made higher than the other side. In the optical condenser installation step, the optical condenser may be installed so that the orientation of the one side of the first rotational axis with respect to the other side when the first rotational axis is set to the downward state in the first rotary shaft angle setting step, and the orientation of the one side of the first rotational axis with respect to the other side when the first rotational axis is set to the upward state become reverse orientations.

In the setting method, even if the angle range of the mirrors that are turned with the second rotational axis as a center is a limited range, an angle range to be used can be included within the angle range of the mirrors that are turned with the second rotational axis as a center.

Additionally, an optical condenser related to the invention is an optical condenser that includes a mirror structure having one or more mirrors and reflects sunlight with the mirrors of the mirror structure to condense the sunlight onto a predetermined condensed position. The optical condenser includes a first driving part that turns the mirrors with a first rotational axis as a center, a second driving part that turns the mirrors with a second rotational axis perpendicular to the first rotational axis as a center, and an elevation angle changing part that changes an angle of the first rotational axis with respect to the horizontal surface. An angle range of the mirrors that are turned with the second rotational axis as a center in the second driving part is within a predetermined angle range on the basis of the first rotational axis. The elevation angle changing part changes the angle of the first rotational axis between a downward state where one side of the first rotational axis is made equal to or lower than the other side on the basis of the second rotational axis and an upward state where the one side is made higher than the other side.

In the optical condenser, even if the angle range of the mirrors that are turned with the second rotational axis as a center is a limited range, an angle range to be used can be included within the angle range of the mirrors that are turned with the second rotational axis as a center.

Advantageous Effects of Invention

In the invention, if the sunlight reflected by the mirror structure is first made to be radiated to the condensed position, the light of the sun making the diurnal motion can be radiated to the fixed condensed position, basically and simply by turning the mirror structure with one rotational axis as a center from then.

Hence, according to the invention, the control system of the driving device can be simplified, and the energy consumption of the driving device can be suppressed.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is an explanatory view showing the configuration of a heat collection apparatus in an embodiment related to the invention.

FIG. **2** is a plan view of the heat collection apparatus in the embodiment related to the invention.

FIG. **3** is a schematic perspective view of a heliostat in the embodiment related to the invention.

FIG. **4** is a back view of the heliostat in the embodiment related to the invention.

FIG. **5** is a side view of the heliostat in the embodiment related to the invention.

FIG. **6** is a plan view of the heliostat in the embodiment related to the invention.

FIG. **7** is a view showing a mirror structure in the embodiment related to the invention, FIG. **7**(*a*) is a back view of the mirror structure, FIG. **7**(*b*) is a bottom plan view of the mirror structure, and FIG. **7**(*c*) is a sectional side view of the mirror structure.

FIG. **8** is an explanatory view of a mirror in the embodiment related to the invention.

FIG. **9** is a cross-sectional view around respective rotary shafts in the embodiment related to the invention.

FIG. **10** is an explanatory view showing the correlation among the optical axis, gravity center, and respective rotational axes of the mirror structure in the embodiment related to the invention.

FIG. **11** is a back view (the rotational angle of a first rotary shaft is 0°) of a first drive mechanism in the embodiment related to the invention.

FIG. **12** is a back view (the rotational angle of the first rotary shaft is 45°) of the first drive mechanism in the embodiment related to the invention.

FIG. **13** is a back view (the rotational angle of the first rotary shaft is 90°) of the first drive mechanism in the embodiment related to the invention.

FIG. **14** is a back view (the rotational angle of the first rotary shaft is −45°) of the first drive mechanism in the embodiment related to the invention.

FIG. **15** is a back view (the rotational angle of the first rotary shaft is −90°) of the first drive mechanism in the embodiment related to the invention.

FIG. **16** is a side view of the first drive mechanism in the embodiment related to the invention.

FIG. **17** is an explanatory view showing a four-link mechanism in the embodiment related to the invention.

FIG. **18** is a perspective view of a supporting base in the embodiment related to the invention.

FIG. **19** is a back view of the supporting base in the embodiment related to the invention.

FIG. **20** is a flowchart showing a setting procedure of a rotational axis in the embodiment related to the invention.

FIG. **21** is an explanatory view (Step **1**) showing a setting method of a first rotational axis in the embodiment related to the invention.

FIG. **22** is an explanatory view (Step **2**) showing the setting method of the first rotational axis in the embodiment related to the invention.

FIG. **23** is an explanatory view (Step **3**) showing the setting method of the first rotational axis in the embodiment related to the invention.

FIG. **24** is an explanatory view showing the orientation of the first rotational axis in a plurality of heliostats in the embodiment related to the invention.

FIG. **25**A is an explanatory view showing the rotational angle range of a second rotary shaft in a downward state in the embodiment related to the invention.

FIG. **25**B is an explanatory view showing the rotational angle range of the second rotary shaft in an upward state in the embodiment related to the invention.

FIG. **26** is an explanatory view showing rotational angle changes of the second rotary shaft accompanying seasonal changes in the embodiment related to the invention.

FIG. **27** is a back view of a mirror structure in a modification example of the embodiment related to the invention.

DESCRIPTION OF EMBODIMENTS

Hereinafter, an embodiment of a heat collection apparatus equipped with an optical condenser related to the invention will be described in detail with reference to the drawings.

A heat collection apparatus **1** of the present embodiment, as shown in FIG. **1**, includes a heat receiver **10** to which sunlight is radiated, a tower facility **20** to which the heat receiver **10** is fixed on an upper part, a plurality of heliostats **30** as optical condensers that reflect sunlight with a mirror and radiate the sunlight to the heat receiver **10**, and a control device **2** that controls the plurality of heliostats **30**.

the heat receiver **10** has a heat receiving part **11** to which sunlight is radiated, and a casing **12** that covers the heat receiving part **11**. A working fluid, such as water or air, is supplied into the heat receiving part **11**, and the working fluid is heated with the heat from the sunlight. When the working fluid is air, the heat collection apparatus **1** can constitute a solar power generation apparatus by further including a gas turbine that is driven with heated air and a generator that generates electricity with the driving of the gas turbine. In addition, in this example, the heat energy from the heat receiver **10** is utilized for generation of electrical energy, this heat energy may be utilized for generation of steam, and this steam may be utilized for generation of electrical energy.

As shown in FIG. **2**, the plurality of heliostats **30** are dotted within a ring-shaped region with the tower facility **20** as a center. In other words, the plurality of heliostats **30** are arranged 360° in a circumferential direction with the tower facility **20** as a center, and the plurality of heliostats are also arranged in far and near directions on the basis of the tower facility **20**. In addition, here, the plurality of heliostats **30** are arranged within the ring-shaped region with the tower facility **20** as a center. However, the plurality of heliostats **30** may be arranged within a fan-shaped region or a rectangular region that has the tower facility **20** as a pivot.

The tower facility **20**, as shown in FIG. **1**, has four posts **21** that extend in a vertical direction, a plurality of beams **22** that connect the four posts **21** to each other, and a storage room **23** that stores the heat receiver **10**. The posts **21** and the beams **22** of the tower facility **20** are arranged so as not to be present on a light path of the sunlight that is reflected with the mirrors of the heliostats **30** and is directed to the heat receiver **10**.

The heliostat **30**, as shown in FIGS. **3** to **6**, includes a mirror structure **31** having a mirror **32** that reflects sunlight, a driving device **40** that directs the mirror **32** of the mirror structure **31** in a target direction, and a supporting base **80** that supports these. In addition, the driving device **40** is a device that turns the mirror structure **31** with a first rotational axis A**1** and a second rotational axis A**2** orthogonal to each other as centers, respectively, as will be described below in more detail.

The mirror structure **31**, as shown in FIG. **7**, has two mirrors **32**, a back reinforcing plate **33** adhered to a back face of the respective mirrors **32**, and a supporting frame **35** that supports a back face of the back reinforcing plate **33**.

The two mirrors **32**, as shown in FIG. **8**, have the same size and form the same oblong plate shape. In the mirror structure **31** of the present embodiment, the reflecting surfaces of the two mirrors **32** form one symmetrical plane of revolution, specifically, a paraboloid of revolution. An apex of the paraboloid of revolution is located at a midpoint of the two mirrors **32**. Hereinafter, in the present embodiment, the apex of the paraboloid of revolution is referred to as a principal point Q**1** of the mirror structure **31**, and an axis passing through the principal point Q**1** and extending in a normal direction with respect to a reflecting surface, that is, a symmetrical axis of revolution of the symmetrical plane of revolution is referred to as an optical axis Ao of the mirror structure **31**.

As mentioned above, the back reinforcing plates **33** are adhered to the whole back faces of the two mirrors **32**, respectively. The back reinforcing plate **33** is formed of a thin steel plate, a thin aluminum alloy plate, a resin plate, or the like, and is molded so as to form a concavo-convex shape in its thickness direction. The back reinforcing plate **33** is adhered to the back face of the mirror **32** via an adhesive at top portions of convex portions of the concavo-convex shape. It is preferable that the adhesive that adheres at least portions between the mirror **32** and the back reinforcing plate **33** to each other be, for example, an elastic silicon-based or denatured silicon-based adhesive having elasticity, in order to absorb a thermal expansion difference caused by a difference between the coefficient of thermal expansion of the mirror **32** and the coefficient of thermal expansion of the back reinforcing plate **33**. Meanwhile, in the back reinforcing plate **33**, a supporting frame **35** is joined to portions that are relatively recessed with respect to the convex portions by welding or adhesion.

The supporting frame **35** has a plurality of supporting beam members **36**, and a connecting member **37** that connects the plurality of supporting beam members **36** to each other. The cross-sectional shape of the supporting beam member **36** is a groove type or an angular pipe type. The plurality of supporting beam members **36** are joined to the back reinforcing plate **33** so that the longitudinal direction thereof faces a radiation direction from the optical axis Ao of the mirror structure **31**. Specifically, in the present embodiment, two supporting beam members **36** are provided with respect to one back reinforcing plate **33**. One end portion of each supporting beam member **36** is directed to an optical axis Ao side, the other end portion thereof is directed to a corner side of the back reinforcing plate **33**, that is, a corner side of the mirror **32**, and two supporting beam members **36** are provided at the back reinforcing plate **33** so as to form a V-shape. In addition, here, two supporting beam members **36** are provided with respect to one back reinforcing plate **33**, that is, one mirror **32**. However, three or more supporting beam members may be provided from a viewpoint of strength.

The connecting member **37** has a connecting beam **38** that connects two supporting beam members **36** of one back reinforcing plate **33** to each other, a columnar shaft **42** that connects the connecting beam **38** on one back reinforcing plate **33** side and the connecting beam **38** on the other back reinforcing plate **33** side to each other, a T-shaped pipe **54** through which the shaft **42** is inserted, an arm plate **39***a* that has one end portion fixed to the connecting beam **38** and extends along the edge of the back reinforcing plate **33**, and a spacing holding rod **39***b* that connects an end portion of the arm plate **39***a* on one back reinforcing plate **33** side and an end portion of the arm plate **39***a* on the other back reinforcing plate **33** side to each other.

A central axis of the shaft **42** that connects the connecting beams **38** to each other, as shown in FIGS. **3** and **10**, is orthogonal to the optical axis Ao, and passes through the principal point Q**1** that is the apex of the paraboloid of revolution of the mirror structure **31**. Additionally, the shaft **42**, as shown in FIG. **9**, enters a portion **54***a* equivalent to a horizontal line of the T-shaped pipe **54**, and is supported by bearings **43** provided inside the T-shaped pipe **54** so as to be rotatable around its own central axis. In the present embodiment, the shaft **42** forms a second rotary shaft, and the central axis of the shaft **42** forms a second rotational axis A**2**. Hence, the shaft **42** is hereinafter referred to as the second rotary shaft **42**.

Each arm plate **39***a*, as shown in FIG. **7**, extends in a direction perpendicular to the second rotary shaft **42**, and has one end portion fixed to the connecting beam **38** as mentioned above. The other end portion of one arm plate **39***a* of the two arm plates **39***a* and the other end portion of the other arm plate **39***a* are connected to each other by the spacing holding rod **39***b*, as mentioned above. The spacing holding rod **39***b* extends in a direction parallel to the second rotary shaft **42**.

In the present embodiment, as mentioned above, the shaft of the connecting member **37** forms the second rotary shaft **42**, and the central axis of the shaft forms the second rotational axis A**2**. Additionally, the first rotational axis A**1** orthogonal to the second rotational axis A**2**, as shown in FIGS. **3** and **10**, also passes through the principal point Q**1** that is the apex of the paraboloid of the mirror structure **31**, similar to the second rotational axis A**2**. That is, in the present embodiment, an intersection point between the first rotational axis A**1** and the second rotational axis A**2** and the principal point Q**1** of the mirror structure **31** coincide with each other.

The driving device **40**, as shown in FIGS. **3** to **6**, has a first driving part **51** that turns the respective mirrors **32** around the first rotational axis A**1**, a second driving part **41** that turns the respective mirrors **32** around the second rotational axis A**2**, and an elevation angle changing part **70** that changes the angle of the first rotary shaft with respect to the horizontal surface.

The second driving part **41** has the aforementioned second rotary shaft **42** having the second rotational axis A**2** as a central axis, the aforementioned bearing **43** (FIG. **9**) that rotatably supports the second rotary shaft **42** around the second rotational axis A**2**, and a second drive mechanism **45** that turns the respective mirrors **32** with the second rotational axis A**2** as a center.

The second drive mechanism **45** includes a second linear actuator **46**. The second linear actuator **46** has a rod cover **46***a*, and a rod **46***b* that is linearly driven with respect to the rod cover **46***a*. The second linear actuator **46** is arranged so that the linear direction of the rod **46***b* becomes perpendicular to the second rotational axis A**2** at a position apart in a radiation direction from the second rotary shaft **42**. A tip portion of the rod **46***b* is pin-connected to a receiving seat **57** provided at the mirror structure **31**. The receiving seat **57** is provided at a position apart in the radiation direction from the second rotational axis A**2**, on the back face of one back reinforcing plate **33** of the mirror structure **31**.

The first driving part **51** has a first rotary shaft **52** that is orthogonal to the second rotational axis A**2** and has the first rotational axis A**1** passing through the principal point Q**1** as a central axis, two bearings **55** and **56** that rotatably support the first rotary shaft **52** with the first rotational axis A**1** as a center, and a first drive mechanism **60** that turns the respective mirrors **32** around the first rotational axis A**1**.

The first rotary shaft **52** has a first rotary shaft body **53** that has the first rotational axis A**1** as a central axis, and the T-shaped pipe **54** that is a portion of the connecting member **37** in the mirror structure **31**. The second rotary shaft **42** enters the portion **54***a* equivalent to the horizontal line of the T-shaped pipe **54** as mentioned above with reference to FIG. **9**, and is supported by the bearing **43** provided inside the T-shaped pipe **54** so as to be rotatable around the second rotational axis A**2**. Additionally, one end portion of the first rotary shaft body **53** is fitted into a portion **54***b* equivalent to a vertical line of the T-shaped pipe **54**, and the first rotary shaft body **53** is fixed thereto. That is, the T-shaped pipe **54** serves as a shaft connecting member that connects the second rotary shaft **42** and the first rotary shaft body **53** to each other.

In this way, in the present embodiment, the shaft **42** and the T-shaped pipe **54** of the connecting member **37** that are constituent elements of the mirror structure **31** are also constituent elements of the driving device **40**.

One side of the first rotary shaft body **53**, that is, a position distant from the T-shaped pipe **54**, is supported by a rear bearing **56** that is one of the aforementioned two bearings **55** and **56**. Additionally, the other side of the first rotary shaft body **53**, that is, a position near the T-shaped pipe **54**, is supported by a front bearing **55** that is the remaining one of the aforementioned two bearings **55** and **56**. Both the front bearing **55** and the rear bearing **56** are attached to the supporting base **80** or a member extending from the supporting base **80**, as will be described below.

A second actuator supporting beam **58** is provided at an end farther than the rear bearing **56**, on one side of the first rotary shaft body **53**. The rod cover **46***a* of the second linear actuator **46** is pin-connected to the end portion of the second actuator supporting beam **58**. For this reason, in the second linear actuator **46**, the second linear actuator **46** is also integrally turned with the first rotational axis A**1** as a center together with the first rotary shaft **52** if the first rotary shaft **52** rotates with the first rotational axis A**1** as a center.

Here, the operation of the second driving part **41** will be described.

As mentioned above, the second linear actuator **46** is arranged so that the linear direction of the rod **46***b* becomes perpendicular to the second rotational axis A**2** at a position apart in the radiation direction from the second rotational axis A**2**. For this reason, if the rod **46***b* is linearly driven, the mirror structure **31** connected to the tip portion of the rod **46***b* is turned around the second rotational axis A**2**. In this case, the second rotary shaft **42** of the second driving part **41** rotates around the second rotational axis A**2**.

In addition, in the case of the present embodiment, the mirror structure **31** is turned with the second rotational axis A**2** as a center by the second linear actuator **46** attached to the first rotary shaft **52**. Therefore, the turning angle range of the mirror structure **31** around the second rotational axis A**2**, in other words, the rotational angle range of the second rotary shaft **42**, is an angle range based on the first rotary shaft **52**, and is less than 180°. Specifically, the rotational angle range of the second rotary shaft **42** of the present embodiment, for example as shown in FIGS. **25**A and **25**B, is 90° ranging from an angle of about 90° at which the optical axis Ao perpendicular to the second rotary shaft **42** is formed with respect to the first rotary shaft **52** to an angle of about 180° at which the optical axis is formed with respect to the first rotary shaft **52**.

The first driving part **51** will be described again. The first drive mechanism **60** of the first driving part **51**, as shown in FIGS. **11** to **16**, includes a first linear actuator **61** and a four-link mechanism **62**.

The four-link mechanism **62** has a first link piece **63**, a second link piece **64**, a third link piece **65**, and a fourth link piece **66** that are connected to each other. A first end portion **63***a* of the first link piece **63** is fixed to the rear bearing **56**, and a first end portion **64***a* of the second link piece **64** is relatively rotatably connected to the second end portion **63***b* of the first link piece **63** by a pin. Additionally, a first end portion **65***a* of the third link piece **65** is relatively rotatably connected to a second end portion **64***b* of the second link piece **64** by a pin, a first end portion **66***a* of the fourth link piece **66** is relatively rotatably connected to a second end portion **65***b* of the third link piece **65** by a pin, and a second end portion **66***b* of the fourth link piece **66** is fixed to the first rotary shaft **52**.

The first linear actuator **61** has a rod cover **61***a*, and a rod **61***b* that is linearly driven with respect to the rod cover **61***a*. The rear bearing **56** is provided with a first actuator supporting beam **67** that extends in the radiation direction with respect to the first rotational axis A**1**. The rod cover **61***a* of the first linear actuator **61** is relatively rotatably connected to an end portion of the first actuator supporting beam **67** by a pin.

The second link piece **64** is bent in an L shape, and an intermediate portion between the first end portion **64***a* and the second end portion **64***b* of the second link piece **64** is farther from the first rotary shaft **52** than a line segment connecting the first end portion **64***a* and the second end portion **64***b*. The distance from the first end portion **66***a* to the second end portion **66***b* in the fourth link piece **66**, that is, the link length of the fourth link piece **66**, is shorter than the distance from the first end portion **64***a* to the second end portion **64***b* in the second link piece **64**, that is, the link length of the second link piece **64**.

Here, the operation of the first driving part **51** will be described.

As shown in FIG. **11**, the rotational angle of the first rotary shaft **52** when the fourth link piece **66** extends vertically upward from the first rotary shaft **52** is defined as 0°. When the rod **61***b* of the first linear actuator **61** is linearly driven from this state in a direction in which the rod is retracted into the rod cover **61***a*, as shown in FIG. **12**, the second end portion **64***b* of the second link piece **64** is displaced together with the linear driving of the rod **61***b*. As a result, in this drawing, the second link piece rocks in the clockwise direction with the first end portion **64***a* as a center.

The third link piece **65** connected to the second link piece **64** is moved slightly in the clockwise direction by the rocking of the second link piece **64**. If the third link piece **65** is moved slightly in the clockwise direction, the first end portion **66***a* of the fourth link piece **66** is displaced in the clockwise direction with the movement of the third link piece **65**. As a result, the first rotary shaft **52** fixed to the second end portion **66***b* of the fourth link piece **66** rotates in the clockwise direction around the first rotational axis A**1**.

If the rod **61***b* of the first linear actuator **61** is further linearly driven in the direction in which the rod is retracted into the rod cover **61***a*, from the state shown in FIG. **12**, the first rotary shaft **52** rotates further in the clockwise direction through the same process as the above as shown in FIG. **13**. In the present embodiment, the state shown in FIG. **13** is a state where the maximum rotational angle of the first rotary shaft **52** in the clockwise direction is formed. This maximum rotational angle is, for example, 90°.

If the rod **61***b* of the first linear actuator **61** is linearly driven in a direction in which the rod is protruded from the rod cover **61***a*, from the state shown in FIG. **11**, the second link piece **64** is rocked in the counterclockwise direction in this drawing with the first end portion **64***a* as a center, as shown in FIG. **14**. The third link piece **65** connected to the second link piece **64** is moved slightly in the counterclockwise direction by the rocking of the second link piece **64**. If the third link piece **65** is moved slightly in the counterclockwise direction, the first end portion **66***a* of the fourth link piece **66** is displaced in the counterclockwise direction with the movement of the third link piece **65**. As a result, the first rotary shaft **52** fixed to the second end portion **66***b* of the fourth link piece **66** rotates in the counterclockwise direction around the first rotational axis A**1**.

If the rod **61***b* of the first linear actuator **61** is further linearly driven in the direction in which the rod is protruded from the rod cover **61***a*, from the state shown in FIG. **14**, the first rotary shaft **52** rotates further in the counterclockwise direction through the same process as the above as shown in FIG. **15**. In the present embodiment, the state shown in FIG. **15** is a state where the maximum rotational angle of the first rotary shaft **52** in the counterclockwise direction is formed. This maximum rotational angle is, for example, −90°.

As described above, in the present embodiment, the first rotary shaft **52** can be rotated within an angle range of ±90, that is, the angle range of 180°.

Incidentally, in the present embodiment, if a state where the rotational angle of the first rotary shaft **52** shown in FIG. **11** is 0° is defined as a reference state, the fourth link piece **66** inclines at 45° from the reference state when the rotational angle of the first rotary shaft **52** shown in FIG. **12** reaches 45°. However, the second link piece **64** of which second end portion is displaced by the first linear actuator **61** inclines only at 22.5° from the reference state.

Additionally, the fourth link piece **66** inclines at 90° from the reference state when the rotational angle of the first rotary shaft **52** shown in FIG. **13** reaches 90°. However, the second link piece **64** of which second end portion is displaced by the first linear actuator **61** inclines only at 45° from the reference state.

That is, in the present embodiment, if the second link piece **64** is turned by the first linear actuator **61**, the fourth link piece **66** is turned at an angle of twice as much as the turning angle of the second link piece **64**. As shown in FIG. **17**, this is because, in the present embodiment, even when the amounts of displacement of the end portions (the second end portion **64***b* in the second link piece **64** and the first end portion **66***a* in the fourth link piece **66**) of the respective link pieces **64** and **66** on the turning side are nearly the same, the link length of the fourth link piece **66** is shorter than the link length of the second link piece **64**, and therefore, the turning angle of the fourth link piece **66** becomes greater than the turning angle of the second link piece **64**.

Accordingly, in the present embodiment, even if the second link piece **64** is slightly turned by the linear driving of the first linear actuator **61**, the fourth link piece **66** can be relatively largely turned, and the rotational angle of the first rotary shaft **52** can be increased. Hence, in the present embodiment, the rotational angle range of the first rotary shaft **52** can be widened.

Additionally, in the present embodiment, as mentioned above, the second link piece **64** is bent in an L shape so that the intermediate portion between the first end portion **64***a* and the second end portion **64***b* of the second link piece **64** is farther from the first rotary shaft **52** than the line segment connecting the first end portion **64***a* and the second end portion **64***b*. For this reason, in the present embodiment, contact with the first rotary shaft **52** can be avoided, and the turning angle range of the second link piece **64** can be widened. Hence, in the present embodiment, the rotational angle range of the first rotary shaft **52** can also be widened from this viewpoint. Additionally, in the present embodiment, the relationship between axial force and torque and the relationship between a stroke and a rotational angle can be predetermined relationships of one-to-one correspondence.

As described above, in the present embodiment, the first rotary shaft **52** is rotated not by rotating the first rotary shaft **52** with a rotary motor, but by turning a link piece connected to the first rotary shaft **52** with the first linear actuator **61**. Thus, an increase in the weight of a rotational driving source of the first rotary shaft **52** can be suppressed while ensuring a large rotary torque. Moreover, in the present embodiment, the first rotary shaft **52** is rotated by turning the link piece with the first linear actuator **61**. However, as mentioned above, the rotational angle range of the first rotary shaft **52** can be widened by configuring a special link mechanism.

The supporting base **80**, as shown in FIGS. **5**, **18**, and **19**, has a base plate **81** that is placed at an installation position of the heliostat **30**, a post **82** that is fixed on the base plate **81**, a plurality of ribs **83** that are provided along generatrices of the post **82**, and a shaft supporting base **85** that supports the first rotary shaft **52**.

The post **82** forms a rotary body shape that is formed by rotating an isosceles trapezoid around a central axis of this isosceles trapezoid, that is, forms a truncated cone shape, and a portion equivalent to the bottom of the truncated cone forms the bottom of the post **82**. The ribs are provided from a lower end of the post **82** to an upper end thereof along the generatrices of the post **82**.

The shaft supporting base **85** has a pair of arm plates **86** that face each other at a distance from each other, and a connecting plate **87** that connects both end portions of the pair of arm plates **86** to each other. The connecting plate **87** of the shaft supporting base **85** is fixed to the post **82**. Additionally, as shown in FIG. **9**, a front bearing **55** that rotatably supports the first rotary shaft **52** around the first rotational axis A**1** is arranged between the pair of arm plates **86**. The front bearing **55** is provided with an elevation angle changing shaft **88** that is perpendicular to the first rotational axis A**1** and extends in the horizontal direction. The elevation angle changing shaft **88** passes through the arm plates **86** of the shaft supporting base **85**, and are supported by the arm plates **86** so as to be rotatable around its own center. Hence, the angle of the first rotary shaft **52** with respect to the horizontal surface can be changed by being turned with the elevation angle changing shaft **88** as a center.

One end portion of a turnbuckle **71** (FIG. **5**) is connected to one rear bearing **56** that rotatably supports the first rotary shaft **52** around the first rotational axis A**1** by a pin. The other end portion of the turnbuckle **71** is connected to an intermediate portion of the post **82** or the rib **83** of the supporting base **80** in a height direction by a pin. In addition, the turnbuckle **71** has a trunk frame **72** that has female threads formed at both ends thereof, and screw rods **73***a* and **73***b* that are screwed into the respective end portions of the trunk frame **72**, and the mutual spacing between both the screw rods **73***a* and **73***b* can be changed by rotating the trunk frame **72**.

The turnbuckle **71** serves to rotate the trunk frame to change the mutual spacing between both the screw rods **73***a* and **73***b* to thereby change the angle of the first rotary shaft **52** at a target angle with respect to the horizontal surface while maintaining this angle. Accordingly, in the present embodiment, the elevation angle changing part **70** is constituted by the turnbuckle **71**, the elevation angle changing shaft **88** provided at the rear bearing **56**, and the shaft supporting base **85** that supports the elevation angle changing shaft **88**. In addition, here, the turnbuckle **71** is used for the elevation angle changing part **70** that changes the angle of the first rotary shaft **52** with respect to the horizontal surface. However, the invention is not limited to the turnbuckle **71**. For example, those having a linear actuator, a rack and pinion mechanism that converts a rotational motion into a rectilinear motion, and a rotary motor that rotates the pinion of the mechanism may be used.

Incidentally, in the present embodiment, as mentioned above with reference to FIGS. **3** and **10**, the intersection point between the first rotational axis A**1** and the second rotational axis A**2** and the principal point Q**1** of the mirror structure **31** coincide with each other. For this reason, in the present embodiment, the principal point Q**1** of the mirror structure **31** is not moved even if the mirror structure **31** is turned around the first rotational axis A**1** or is turned around the second rotational axis A**2**. In other words, in the present embodiment, the principal point Q**1** of the mirror structure **31** is a fixed point.

In this way, in the present embodiment, the principal point Q**1** of the mirror structure **31** is not moved even if the mirror structure **31** is turned around the first rotational axis A**1** or is turned around the second rotational axis A**2**. Therefore, the relative position between the principal point Q**1** of the mirror structure **31** and the heat receiving part **11** (heat collection position) of the heat receiver **10** does not change, either.

Hence, in the present embodiment, if the optical axis Ao of the mirror structure **31** is directed to a direction in which an angle formed between an imaginary line connecting the sun at that time and the principal point Q**1** of the mirror structure **31** and an imaginary line connecting the principal point Q**1** of the mirror structure and a condensed position is bisected, the sunlight reflected by the mirror **32** of the mirror structure **31** can precisely continue being radiated to the heat receiving part **11** of the heat receiver **10**.

Additionally, a gravity center Q**2** of the mirror structure **31** described above is present at a position slightly shifted from the principal point Q**1** of the mirror structure **31** to the supporting beam member **36** side on the basis of the mirror **32**, on the optical axis Ao of the mirror structure **31**. It should be noted herein that the gravity center Q**2** is present within an intersecting portion between the first rotary shaft **52** and the second rotary shaft **42**. For this reason, in the present embodiment, even if the mirror structure **31** is turned around the first rotational axis A**1** or is turned around the second rotational axis A**2**, the position of the gravity center Q**2** hardly moves, and the moment to turn the mirror structure **31** itself around the first rotational axis A**1** or the second rotational axis A**2** is hardly produced due to the weight of the mirror structure **31** itself.

Accordingly, in the present embodiment, the driving force for turning the mirror structure **31** can be made small, and even if the rigidity of the first rotary shaft **52** or the second rotary shaft **42**, and the rigidity of a supporting structure including bearings that rotatably supports the rotary shafts **52** and **42**, or the like are slightly small, the mirror structure **31** can be stably supported.

In this way, in the present embodiment, since the rigidity of the first rotary shaft **52** or the second rotary shaft **42** can be made small, it is also possible to attain miniaturization and weight reduction of these shafts.

Moreover, the gravity center Q**2** of the mirror structure **31** of the present embodiment is present on the post **82** that is a main constituent member of the supporting base **80**. More precisely, the gravity center is present on an upper surface of the truncated cone-shaped post **82**. For this reason, in the present embodiment, even if the mirror structure **31** is turned around each rotational axe A**1** or A**2**, there is almost no overturning moment applied to the base plate **81** side of the post **82** caused by the weight of the mirror structure **31**.

Hence, in the present embodiment, miniaturization and weight reduction of the supporting base **80** can be realized. In addition, here, the miniaturization of the supporting base **80** includes making the diameter of the post **82** constituting the supporting base **80** small without making the height of the supporting base **80** low, making the thickness or width of the ribs **83** small, or omitting the ribs **83**.

Additionally, in the present embodiment, the first linear actuator **61** and the four-link mechanism **62** as a driving source that rotates the first rotary shaft **52** are greatly apart from the intersection point Q**1** between the first rotational axis A**1** and the second rotational axis A**2**. Specifically, the distance from the intersection point Q**1** to the first linear actuator **61** and the four-link mechanism **62** is much greater than the distance from the intersection point Q**1** to the front bearing **55** that rotatably supports the first rotary shaft **52**. Moreover, the second linear actuator **46** as a driving source that rotates the second rotary shaft **42** is also greatly apart from the intersection point Q**1** between the first rotational axis A**1** and the second rotational axis A**2**. Specifically, the distance from the intersection point Q**1** to the second linear actuator **46** is much greater than the distance from the intersection point Q**1** to the bearing **43** that rotatably supports the second rotary shaft **42**. That is, in the present embodiment, the first linear actuator **61** and the four-link mechanism **62**, and the second linear actuator **46** are greatly apart from the intersection point Q**1** between the first rotary shaft **52** and the second rotary shaft **42**.

Hence, in the present embodiment, the respective actuators **61** and **46** as driving sources are not present in the vicinity of the intersection point Q**1**. Therefore, the mutual distance of the two mirrors **32** where the intersection point Q**1** is located at the midpoint can be made small, and the moment applied to the intersection point Q**1** between the first rotational axis A**1** and the second rotational axis A**2** when wind load is received can be made small.

Next, a setting method of the respective rotational axes A**1** and A**2** of the heliostats **30** described above will be described.

In an astronomical telescope, an equatorial telescope is used in order to facilitate tracking of stars, the sun, or the like. This equatorial telescope has a right-ascension axis set parallel to the earth's axis, and a declination axis perpendicular to this right-ascension axis. In this equatorial telescope, if the astronomical telescope is turned around the right-ascension axis and the declination axis and the optical axis of the astronomical telescope are first directed to a target celestial body, it is then possible to respond to the diurnal motion of the celestial body simply by turning the astronomical telescope around the right-ascension axis.

Accordingly, even in a heliostat, if a driving device of a mirror structure has two rotary shafts orthogonal to each other, the sun that makes a diurnal motion can be tracked by setting one rotary shaft to be parallel to the earth's axis and turning the mirror structure with the rotary shaft as a center. However, the heliostat needs to reflect the light from the sun that makes the diurnal motion to radiate this light to the fixed heat receiver **10**. For this reason, even if one rotary shaft of the two orthogonal rotary shafts is set parallel to the earth's axis similar to the astronomical telescope, if the mirror structure is not turned around the two rotary shafts, the light from the sun that makes the diurnal motion cannot be radiated to the fixed heat receiver.

Thus, in the following, a rotational axis setting method that can turn the mirror structure, basically, with one rotary shaft as a center to radiate the light from the sun making the diurnal motion to the fixed heat receiver **10** will be described according to the flowchart shown in FIG. **20**.

First, as shown in FIGS. **21** and **22**, position data on the earth where the mirror structure **31** is installed, global position data of the heat receiving part **11** of the heat receiver **10** becoming a condensed position Pc of sunlight, and solar position data based on the position of the mirror structure **31** at a plurality of times on a predetermined day in one year are acquired (S**1**).

The mirror structure **31** and the condensed position data are global coordinate data, that is, data shown by the latitude and the longitude. In addition, although the position data of the mirror structure **31** is precisely the position data of the principal point Q**1** that is a fixed point of the mirror structure **31**, since precise data is not required so much here, it is sufficient if data on positions where the heliostats **30** are installed is provided.

The solar position data based on the position of the mirror structure **31** is data shown by the azimuth of the sun Ps from the position of the mirror structure **31**, and the elevation angle of the sun Ps. Additionally, the predetermined day in one year is, for example, the day of the spring equinox or the autumn equinox, or the like. Additionally, the number of the solar position data is a number that can specify the track of the sun Ps on the predetermined day, specifically, three or more.

Next, the optical axis vectors Vo indicating the direction of the optical axis Ao of the mirror structure **31** that directs the light from the sun Ps at a plurality of times on the predetermined day to the condensed position Pc are obtained for each of the plurality of times (S**2**). The direction of the optical axis Ao of the mirror structure **31** that directs the light from the sun Ps at a certain time to the condensed position Pc is a direction in which an angle formed between an imaginary line L**1** connecting the sun Ps and the principal point Q**1** of the mirror structure **31** and an imaginary line L**2** connecting the principal point Q**1** of the mirror structure and the condensed position Pc is bisected. In the present embodiment, a unit vector that faces this direction is defined as an optical axis vector Vo.

The track of direction segments indicated by the optical axis vectors Vo accompanying the diurnal motion of the sun Ps draws a side peripheral surface of a certain cone. That is, the track of the optical axis Ao of the mirror structure **31** that directs the light from the sun Ps making the diurnal motion to the condensed position Pc draws a side peripheral surface of a cone. Thus, next, a cone C having generatrices along which the direction segments indicated by the optical axis vectors Vo for each of the plurality of times extend is determined, and a cone central axis vector Va indicating the direction of a central axis of the cone C is obtained (S**3**). In addition, this cone central axis vector Va is also a unit vector.

Then, the first rotational axis A**1** of the heliostat is directed to the direction indicated by the cone central axis vector Va (S**4**). If the direction of the first rotational axis A**1** is made to coincide with the direction of the cone central axis vector Va in this way, and if the mirror structure **31** is first turned around the second rotational axis A**2** so that the sunlight reflected by the mirror structure **31** is radiated to the condensed position Pc, basically, the mirror structure **31** is simply turned around the first rotational axis A**1** from then, whereby the track of the direction segments indicated by the actual optical axis vectors Vo accompanying the diurnal motion of the sun Ps forms the side peripheral surface of the cone C determined in Step **3**. That is, in the present embodiment, the light of the sun Ps making the diurnal motion can be radiated to the fixed condensed position Pc by causing the direction of the first rotational axis A**1** to coincide with the direction of the cone central axis vector Va to thereby basically and simply turn the mirror structure **31** around the first rotational axis A**1**.

Here, as mentioned above, the plurality of heliostats **30** are installed in an installation region of the heat collection apparatus. Naturally, relative positions with respect to the heat receiver **10** for each of the plurality of heliostats **30** vary. For this reason, the angles of the first rotational axes A**1** with respect to the horizontal surface in the plurality of heliostats **30** vary as shown in FIGS. **21** and **23**. Moreover, the orientations of the first rotational axes A**1** in the plurality of heliostats **30** also vary as shown in FIG. **24**. In addition, in the heliostats **30** drawn in a T-shape in FIG. **24**, a portion equivalent to a horizontal line of the T-shape shows the mirror structure **31**, and a portion equivalent to a vertical line of the T-shape shows the first rotary shaft **52**.

For this reason, in Step **4**, first, the mirror structures **31** are located at positions indicated by the position data of the mirror structure **31** acquired in Step **1**, and the heliostats **30** are installed so that the orientations of the first rotational axes A**1** become orientations indicated by the cone central axis vector Va (S**5**).

Next, the first rotational axis A**1** is set so that the angle of the first rotational axis A**1** with respect to the horizontal surface becomes the angle of the cone central axis vector Va with respect to the horizontal surface (S**6**). In this case, the angle of the first rotary shaft **52** with respect to the horizontal surface is set by operating the turnbuckle **71** of the elevation angle changing part **70**.

Incidentally, in the present embodiment, the rotational angle range of the second rotary shaft **42**, as mentioned above, is such that the optical axis Ao perpendicular to the second rotational axis A**2** is 90° that is 90° to 180° on the basis of the first rotary shaft **52**. For this reason, for example, as shown in FIG. **25**A, one side A**1***a* of the first rotational axis A**1** is made equal to or lower than the other side A**1***b*. Therefore, in the case of a downward state where the angle of the first rotational axis A**1** in the counterclockwise direction with respect to the horizontal surface H is set to 340° (−20°), the orientation of the optical axis Ao can be changed within a range of 70° to 160° in the counterclockwise direction with respect to the horizontal surface H by rotating the second rotary shaft **42**.

Meanwhile, when the angle of the optical axis Ao in the counterclockwise direction with respect to the horizontal surface H at which the sunlight can be radiated to the condensed position Pc is within a range of 0° to 70°, the following processing is performed in a heliostat installation step (S**5**) and a first rotary shaft angle setting step (S**6**).

In the heliostat installation step (**S5**), as shown in FIG. **25**B, the heliostat **30** is installed so that the orientation of the one side A**1**a of the first rotational axis A**1** with respect to the other side A**1**b thereof becomes an orientation reverse to the orientation when the first rotational axis is set to the aforementioned downward state.

Then, in the first rotary shaft angle setting step (**S6**), an upward state where the one side A**1**a of the first rotational axis A**1** is made higher than the other side A**1**b and the angle of the first rotational axis A**1** in the counterclockwise direction with respect to the horizontal surface H is made to be 340° (−20°) is set. That is, the one side A**1**a of the first rotational axis A**1** is made higher than the other side A**1**b, and the angle of the other side A**1**b of the first rotational axis A**1** with respect to the horizontal surface H is set to the angle of the one side A**1**a of the first rotational axis A**1** with respect to the horizontal surface H in the downward state.

As described above, if the heliostat **30** is installed and the direction of the first rotational axis A**1** is set, the orientation of the optical axis Ao can be changed within a range Rr of −20° to 70° in the counterclockwise direction with respect to the horizontal surface H by rotating the second rotary shaft **42**.

In addition, as mentioned above, when the angle of the first rotary shaft **52** with respect to the horizontal surface is changed, it is possible to respond to this change by rotating the trunk frame **72** of the turnbuckle **71** to change the mutual spacing between both the screw rods **73**a and **73**b. Additionally, when the change range of the angle of the first rotary shaft **52** with respect to the horizontal surface is changed, it is possible to respond to this change by using different lengths of both the screw rods **73**a and **73**b themselves of the turnbuckle **71**.

As described above, in the driving device **40** of the present embodiment, the rotational angle range of the second rotary shaft **42** is within a predetermined range on the basis of the first rotational axis A**1**. However, by causing the orientation of the one side A**1**a with respect to the other side A**1**b of the first rotational axis A**1** to be a reverse orientation and by properly selecting whether the first rotational axis A**1** is brought into the downward state or brought into the upward state, the rotational angle range of the use schedule of the second rotational axis A**2** can be included within a rotational angle range to be used, of the second rotational axis A**2** after the installation of the heliostat **30**.

From the above, the installation of the heliostat **30** and the setting of the first rotational axis A**1** are ended.

In order to radiate the sunlight to the condensed position Pc with the mirrors **32** of the heliostat **30** after the end of the installation of the heliostat **30** and the end of the setting of the first rotational axis A**1**, the second rotary shaft **42** is rotated so that the sunlight reflected by the mirror structure **31** is radiated to the condensed position Pc, in other words, the second rotary shaft **42** is rotated to turn the mirror structure **31** around the second rotational axis A**2**. In this way, if the sunlight reflected by the mirror structure **31** is made to be radiated to the condensed position Pc, as mentioned above, the light of the sun making the diurnal motion can be radiated to the fixed condensed position Pc basically and simply by turning the mirror structure **31** around the first rotational axis A**1** from then.

Accordingly, in the present embodiment, a control system of the driving device **40** can be simplified, and the energy consumption thereof can be suppressed.

The elevation angle of the sun changes even at the same time of one day if the season changes. If the elevation angle of the sun changes with this seasonal change, the optical axis vector Vo at the same time of one day also changes. As a result, the cone C determined at the time of the setting of the first rotational axis A**1** also changes with the seasonal change. However, the change of the cone C accompanying the seasonal change is confined to a change in the diameter of a bottom surface of the cone C, and there is no change in the direction of a central axis of the cone C. For this reason, in the present embodiment, in order to respond to the change in the elevation angle of the sun accompanying the seasonal change, the rotational angle of the second rotational axis A**2** is changed, in other words, the turning angle of the mirror **32** centered on the second rotary shaft **42** is changed.

Specifically, as shown in FIG. **26**, the rotational angle of the second rotational axis A**2** during the winter solstice and the rotational angle of the second rotational axis A**2** during the summer solstice are changed with respect to the rotational angles of the second rotational axis A**2** at the time of the spring equinox and the autumn equinox. Although a change in the rotational angle of the second rotational axis A**2** accompanying the seasonal change may be performed every day, the change may be performed every several days. Although this change may be manually performed, the everyday rotational angles of the second rotational axis A**2** are stored in the control device **2** in advance, and the second rotary shaft **42** can be automatically rotated through everyday instructions from the control device **2**.

Additionally, in the above embodiment, the first rotational axis A**1** and the second rotational axis A**2** are orthogonal to each other, and the principal point Q**1** of the mirror structure **31** is located on the intersection point between the first rotational axis A**1** and the second rotational axis A**2**. However, if the first driving part that turns the mirrors with the first rotational axis A**1** as a center and the second driving part that turns the mirrors with the second rotational axis perpendicular to the first rotational axis as a center are provided, in any type of driving device, the light of the sun making the diurnal motion can be radiated to the fixed condensed position by executing the above rotational axis setting method to thereby basically and simply turn the mirror structure around the first rotational axis.

Additionally, although the mirror structure **31** having the two mirrors **32** is illustrated in the above embodiment, the invention is not limited to this and can be applied to a mirror structure having one mirror, and a mirror structure having three or more mirrors. Additionally, although the mirror structure **31** having the oblong plate-shaped mirror **32** is illustrated in the above embodiment, the invention is not limited to this, and a mirror structure **31**A having a mirror **32**A with other shapes, for example, a semicircular plate shape as shown in FIG. **27** may be adopted. In addition, when the semicircular plate-shaped mirror **32**A is adopted, interference with an installation surface can be mitigated, and the posts can be shortened.

REFERENCE SIGNS LIST

Q**1**: PRINCIPAL POINT
Q**2**: GRAVITY CENTER
AO: OPTICAL AXIS
A**1**: FIRST ROTATIONAL AXIS
A**2**: SECOND ROTATIONAL AXIS
1: HEAT COLLECTION APPARATUS
2: CONTROL DEVICE
10: HEAT RECEIVER
11: HEAT RECEIVING PART
20: TOWER FACILITY
30: HELIOSTAT (OPTICAL CONDENSER),

31: MIRROR STRUCTURE
32: MIRROR
33: BACK REINFORCING PLATE
35: SUPPORTING FRAME
36: SUPPORTING BEAM MEMBER
37: CONNECTING MEMBER
40: DRIVING DEVICE
41: SECOND DRIVING PART
42: SECOND ROTARY SHAFT
45: SECOND DRIVE MECHANISM
46: SECOND LINEAR ACTUATOR
51: FIRST DRIVING PART
52: FIRST ROTARY SHAFT
60: FIRST DRIVE MECHANISM
61: FIRST LINEAR ACTUATOR
62: FOUR-LINK MECHANISM
63: FIRST LINK PIECE
64: SECOND LINK PIECE
65: THIRD LINK PIECE
66: FOURTH LINK PIECE
70: ELEVATION ANGLE CHANGING PART
71: TURNBUCKLE
80: SUPPORTING BASE
82: POST

The invention claimed is:

1. An optical condenser that includes a mirror structure having one or more mirrors and reflects sunlight with the mirrors of the mirror structure to condense the sunlight onto a predetermined condensed position, the optical condenser comprising:

a first driving part that turns the mirrors with a first rotational axis as a center, and

a second driving part that turns the mirrors with a second rotational axis perpendicular to the first rotational axis as a center,

wherein the first rotational axis is set to be parallel to a central axis of a cone drawn by a track of an optical axis of the mirror structure that directs the light from the sun making a diurnal motion to the condensed position.

2. The optical condenser according to claim **1**,

wherein reflecting surfaces of the one or more mirrors of the mirror structure form one symmetrical plane of revolution, and a symmetrical axis of revolution of the symmetrical plane of revolution constitutes the optical axis of the mirror structure.

3. The optical condenser according to claim **1**, further comprising:

an elevation angle changing part that changes an angle of the first rotational axis with respect to a horizontal surface.

4. The optical condenser according to claim **3**,

wherein an angle range of the mirrors that are turned with the second rotational axis as a center in the second driving part is within a predetermined angle range on the basis of the first rotational axis, and

wherein the elevation angle changing part changes the angle of the first rotational axis with respect to the horizontal surface between a downward state where one side of the first rotational axis is made equal to or lower than the other side on the basis of the second rotational axis and an upward state where the one side is made higher than the other side.

5. A heat collection apparatus comprising:

the optical condenser according to claim **1**; and

a heat receiver that heats a medium by sunlight condensed by the optical condenser.

6. A solar power generation apparatus comprising:

the optical condenser according to claim **1**;

a heat receiver that heats a medium from sunlight condensed by the optical condenser;

a turbine that is driven by the medium heated by the heat receiver; and

a generator that generates electricity through the driving of the turbine.

7. A rotational axis setting method in an optical condenser including a mirror structure having one or more mirrors and a driving device that turns the mirror structure around a rotational axis to direct sunlight reflected by the mirrors of the mirror structure to a predetermined condensed position, the rotational axis setting method comprising:

a data acquisition step of acquiring global position data of the mirror structure, global position data of the condensed position, and solar position data based on the position of the mirror structure for each of a plurality of times on a predetermined day in one year;

an optical axis vector calculating step of obtaining optical axis vectors indicating a direction of an optical axis of the mirror structure that directs the light from the sun at the plurality of times on the predetermined day to the condensed position for each of the plurality of times;

a cone central axis vector calculating step of determining a cone having generatrices along which direction segments of the optical axis vectors for each of the plurality of times extend, and obtaining a cone central axis vector indicating a direction of a central axis of the cone; and

a rotational axis setting step of setting the rotational axis to be parallel to the cone central axis vector.

8. The rotational axis setting method according to claim **7**,

wherein the driving device includes a first driving part that turns the mirrors with a first rotational axis as the rotational axis as a center, and a second driving part that turns the mirrors with a second rotational axis perpendicular to the first rotational axis as a center,

the setting method further comprising:

a step of changing a turning angle of the mirrors centered on the second rotational axis so as to correspond to a change in an elevation angle of the sun accompanying a diurnal change.

9. The rotational axis setting method according to claim **8**,

wherein the rotational axis setting step includes:

an optical condenser installation step of installing the optical condenser so that the mirror structure is located at a position indicated by the position data of the mirror structure acquired in the data acquisition step and the orientation of the first rotational axis becomes the orientation indicated by the cone central axis vector; and

a first rotary shaft angle setting step of setting the first rotational axis so that the angle of the first rotational axis with respect to the horizontal surface becomes the angle of the cone central axis vector with respect to the horizontal surface.

10. The rotational axis setting method according to claim **9**,

wherein an angle range of the mirrors that are turned with the second rotational axis as a center in the second driving part is within a predetermined angle range on the basis of the first rotational axis,

wherein, in the first rotary shaft angle setting step, the first rotational axis is set in a state where the predetermined angle range based on the first rotational axis is able to include a predetermined angle range where the mirrors are turned with the second rotational axis as a center, out of a downward state where the angle of one side of the first rotational axis with respect to the horizontal surface on the basis of the second rotational axis becomes the angle of the cone central axis vector with respect to the horizontal surface and the one side of the first rotational axis is made equal to or lower than the other side, and an upward state where the angle of the other side of the first rotational axis with respect to the horizontal surface becomes the angle of the cone central axis vector with respect to the horizontal surface and the one side of the first rotational axis is made higher than the other side, and

wherein, in the optical condenser installation step, the optical condenser is installed so that the orientation of the one side of the first rotational axis with respect to the other side when the first rotational axis is set to the downward state in the first rotary shaft angle setting step, and the orientation of the one side of the first rotational axis with respect to the other side when the first rotational axis is set to the upward state become reverse orientations.

11. The optical condenser according to claim **2**, further comprising:

an elevation angle changing part that changes an angle of the first rotational axis with respect to a horizontal surface.

12. A heat collection apparatus comprising:

the optical condenser according to claim **2**; and

a heat receiver that heats a medium by sunlight condensed by the optical condenser.

13. A heat collection apparatus comprising:

the optical condenser according to claim **3**; and

a heat receiver that heats a medium by sunlight condensed by the optical condenser.

14. A heat collection apparatus comprising:

the optical condenser according to claim **4**; and

a heat receiver that heats a medium by sunlight condensed by the optical condenser.

15. A solar power generation apparatus comprising:

the optical condenser according to claim **2**;

a heat receiver that heats a medium from sunlight condensed by the optical condenser;

a turbine that is driven by the medium heated by the heat receiver; and

a generator that generates electricity through the driving of the turbine.

16. A solar power generation apparatus comprising:

the optical condenser according to claim **3**;

a heat receiver that heats a medium from sunlight condensed by the optical condenser;

a turbine that is driven by the medium heated by the heat receiver; and

a generator that generates electricity through the driving of the turbine.

17. A solar power generation apparatus comprising:

the optical condenser according to claim **4**;

a heat receiver that heats a medium from sunlight condensed by the optical condenser;

a turbine that is driven by the medium heated by the heat receiver; and

a generator that generates electricity through the driving of the turbine.

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